A TEXTBOOK

ON

SURVEYING AND MAPPING

INTERNATIONAL CORRESPONDENCE SCHOOLS
SCRANTON, PA.

GEOMETRICAL DRAWING
TABLES AND FORMULAS

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CONTENTS

GEOMETRICAL DRAWING

INSTRUMENTS AND MATERIALS

1. A **drawing** is a representation of objects on a plane surface by means of lines or lines and shades. When done by the use of free hand only, it is called **freehand drawing** or **sketching**; when instruments are used, so that greater exactness may be obtained, it is called **instrumental,** or **mechanical, drawing.**

2. All the instruments and materials required for the courses in drawing are mentioned in the following descriptions:

The **drawing board** should be made of well-seasoned, straight-grained pine, the grain running lengthwise. For this Course, the student will need a board of the following dimensions: length over all, 22½ inches; width, 16½ inches.

The drawing board illustrated in Fig. 1 is the one furnished in our students' drawing outfits and can be fully recommended as possessing the qualities a good and accurate board should have. It is made of several pieces of pine wood glued together to the required width of the board. A pair of hardwood cleats is screwed to the back of the board, the screws passing through the cleats in oblong slots with iron bushings, which allow the screws to move freely when drawn by the contraction and expansion of the board. Grooves are cut through half the thickness of the board over the entire back side. These grooves take the transverse resistance out of the wood and allow it to be controlled

by the cleats, at the same time leaving the longitudinal strength nearly unimpaired. In order to provide a perfectly smooth working edge for the head of the T square to slide against a strip of hard wood is let into the short edges

FIG. 1

of the board, and is sawed through in several places, in order to allow for the contraction and expansion of the board. The cleats also raise the board from the table, thus making it

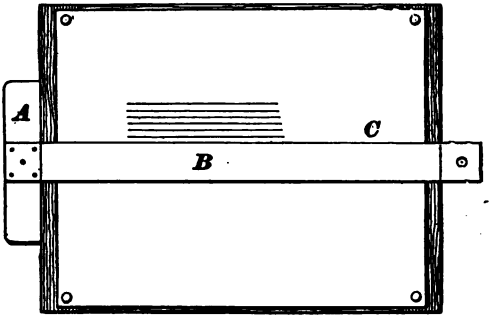


FIG. 2

easier to change the position of the board. When in use, the board is placed so that one of the short edges is at the left of the draftsman, as shown in Fig. 2.

3. The **T square** is used for drawing horizontal straight lines. The head *A* is placed against the left-hand edge of the board, as shown in Fig. 2. The upper edge *C* of the blade *B* is brought very near to the point through which it is desired to pass a line, so that the straight edge *C* of the blade may be used as a guide for the pen or pencil. It is evident that all lines drawn in this manner will be parallel.

Vertical lines are drawn by means of triangles. The triangles most generally used are shown in Figs. 3 and 4, each of which has one right angle. The triangle shown in Fig. 3

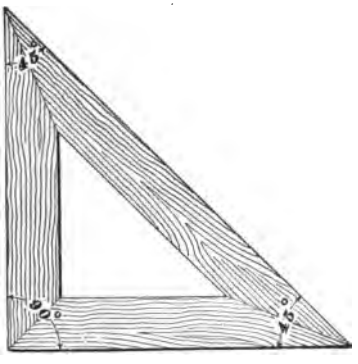


FIG. 3

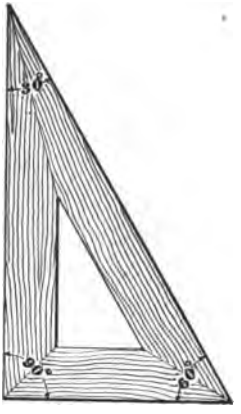


FIG. 4

has two angles of 45° each, and that in Fig. 4 one of 60° and one of 30°. They are called *45°* and *60° triangles*, respectively. To draw a vertical line, place the **T** square in position to draw a horizontal line, and lay the triangle against it, so as to form a right angle. Hold both **T** square and triangle lightly with the left hand, so as to keep them from slipping, and draw the line with the pen or pencil held in the right hand, and against the edge of the triangle. Fig. 5 shows the triangles and **T** square in position.

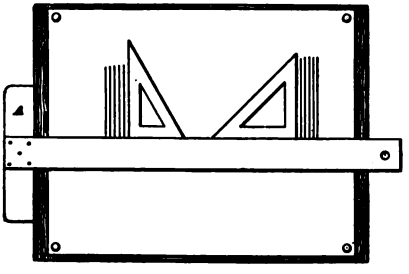


FIG. 5

4. For drawing parallel lines that are neither vertical nor horizontal, the simplest and best way, when the lines are near together, is to place one edge of a triangle, as *a b*, Fig. 6, on the given line *c d*, and lay the other triangle, as *B*, against one of the two edges, holding it fast

with the left hand; then move the triangle A along the edge of B. The edge $a\,b$ will be parallel to the line $c\,d$; and when the edge $a\,b$ reaches the point g, through which it is desired to draw the parallel line, hold both triangles

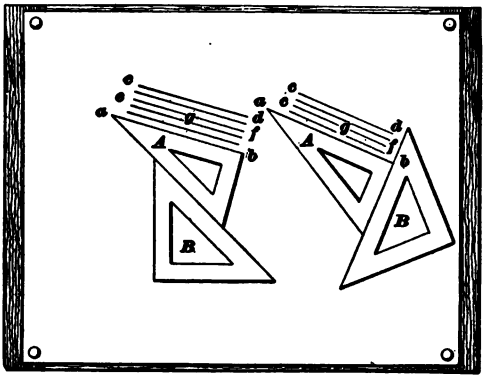


FIG. 6

stationary with the left hand and draw the line $e\,f$ by passing the pencil along the edge $a\,b$. Should the triangle A extend too far beyond the edge of the triangle B after a number of lines have been drawn, hold A stationary with the left hand and shift B along the edge of A with the right hand and then proceed as before.

5. A line may be drawn at right angles to another line which is neither vertical nor horizontal, as illustrated in Fig. 7. Let $c\,d$ be the given line (shown at the left-hand side). Place one of the shorter edges, as $a\,b$, of the triangle B so that it will coincide with the line $c\,d$; then, keeping the triangle in this position, place the triangle A so that its long edge will come against the long edge of B. Now, holding A securely in place with the left hand, slide B along the edge of A with the right hand, when the lines $h\,i$, $m\,n$, etc. may be drawn perpendicular to $c\,d$ along the edge $b\,f$ of the triangle B. The dotted lines show the position of the triangle B when moved along the edge of A.

6. The right-hand portion of Fig. 7 shows another method of accomplishing the same result, and illustrates

how the triangles may be used for drawing a rectangular figure, when the sides of the figure make an angle with the T square such that the latter cannot be used.

Let the side *c d* of the figure be given. Place the *long* side of the triangle *B* so as to coincide with the line *c d*, and bring the triangle *A* into position against the lower side of *B*, as shown. Now, holding the triangle *A* in place with the left hand, revolve *B* so that its other short edge will rest against the long edge of *A*, as shown in the dotted position at *B'*. The parallel lines *c e* and *d f* may now be drawn

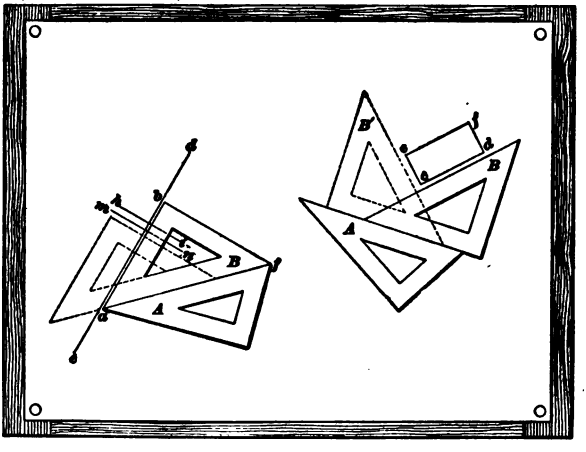


FIG. 7

through the points *c* and *d* by sliding the triangle *B* on the triangle *A*, as described in connection with Fig. 6. Measure off the required width of the figure on the line *c e*, reverse the triangle *B* again to its original position, still holding the triangle *A* in a fixed position with the left hand, and slide *B* upon *A* until the long edge of *B* passes through *e*. Draw the line *e f* through the point *e*, and *e f* will be parallel to *c d*. The student should practice with his triangles before beginning drawing.

7. The **compasses,** next to the T square and triangles, are used more than any other instrument. A pencil and pen point are provided, as shown in Fig. 8, either of which

may be inserted into a socket in one leg of the instrument, for the drawing of circles in pencil or ink. The other leg is fitted with a needle point, which acts as the center about which the circle is drawn. In all good instruments, the needle point itself is a separate piece of round steel wire, held in place in a socket provided at the end of the leg The wire should have a square shoulder at its lower end, below which a fine, needle-like point projects. The *lengthening bar*, also shown in the figure, is used to extend the leg carrying the pen and pencil points when circles of large radii are to be drawn.

The joint at the top of the compasses should hold the legs firmly in any position, and at the same time should permit their being opened or closed with one hand. The joint may be tightened or loosened by means of a screwdriver or wrench, which accompanies the compasses.

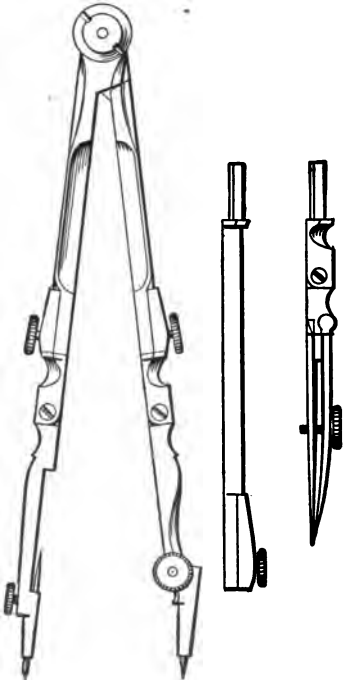


FIG. 8

It will be noticed in Fig. 8 that each leg of the compasses is jointed; this is done so that the compass points may always be kept perpendicular to the paper when drawing circles, as in Fig. 11.

The style of compasses shown in Fig. 8 have what is called a *tongue joint*, in which the head of one leg has a tongue, generally of steel, which moves between two lugs on the other leg. Another common style of joint is the *pivot joint*, in which the head of each leg is shaped like a disk and the two disks are held together in a fork-shaped brace either by means of two pivot screws or by one screw penetrating both disks

The brace that forms a part of this joint is generally provided with a handle, as the shape of the joint makes it rather

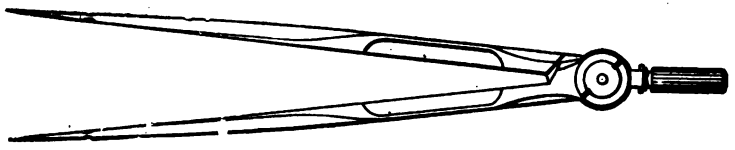


FIG. 9

awkward to hold the compasses by the head, as is usual with instruments provided with tongue joints. In Fig. 9 is shown a common style of pivot joint.

8. The following suggestions for handling the compasses should be carefully observed by those who are beginning the subject of mechanical drawing. Any draftsman who handles his instruments awkwardly will create a bad impression, no matter how good a workman he may be. The tendency of

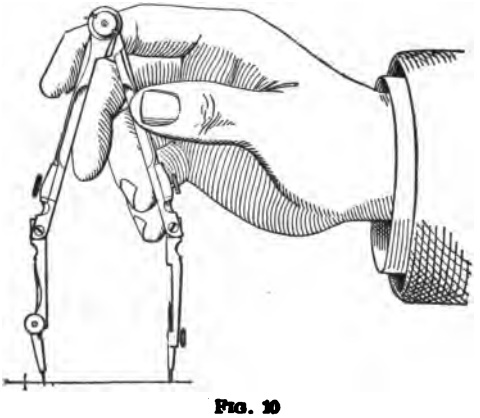


FIG. 10

all beginners is to use both hands for operating the compasses. This is to be avoided. The student should learn at the start to open and close them with one hand, holding them as shown in Fig. 10, with the needle-point leg resting between the thumb and fourth finger, and the other leg between the middle and forefinger. When drawing circles,

hold the compasses lightly at the top between the thumb and forefinger, or thumb, forefinger, and middle finger, as in Fig. 11. Another case where both hands should not be used is in locating the needle point at a point on the drawing about which the circle is to be drawn, unless the left hand is used merely to steady the needle point. Hold the compasses as shown in Fig. 10, and incline them until the under side of the

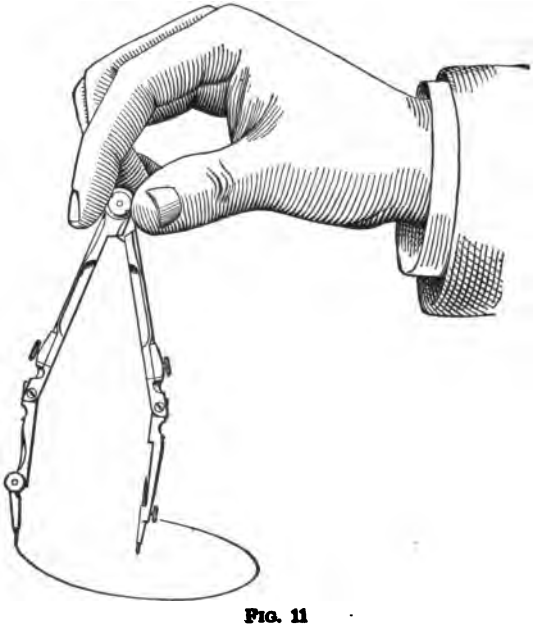


FIG. 11

hand rests upon the paper. This will steady the hand so that the needle point can be brought to exactly the right place on the drawing. Having placed the needle at the desired point, and with it still resting on the paper, the pen or pencil point may be moved out or in to any desired radius, as indicated in Fig. 10. When the lengthening bar is used, both hands must be employed.

9. The compasses must be handled in such a manner that the needle point will not dig large holes in the paper. Keep

the needle point adjusted so that it will be perpendicular to the paper, when drawing circles, and *do not bear upon it.* A slight pressure will be necessary on the pen or pencil point, *but not on the needle point.*

10. The **dividers,** shown in Figs. 9 and 12, are used for laying off distances upon a drawing, or for dividing straight lines or circles into parts. The points of the dividers should be *very* sharp, so that they will not punch holes in the paper larger than is absolutely necessary to be seen. Compasses are sometimes furnished with two steel divider points, besides the pen and pencil points, so that the instrument may be used either as compasses or dividers. This is the kind illustrated in Fig. 12. When using the

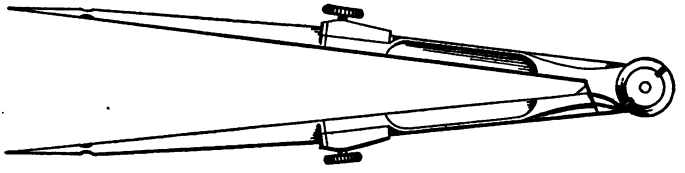


FIG. 12

dividers to space a line or circle into a number of equal parts, hold them at the top between the thumb and forefinger, as when using the compasses, and step off the spaces, turning the instrument alternately to the right and left. If the line or circle does not space exactly, vary the distance between the divider points and try again; so continue until it is spaced equally. When spacing in this manner, great care must be exercised not to press the divider points into the paper; for, if the points enter the paper, the spacing can never be accurately done. The student should satisfy himself of the truth of this statement by actual trial.

11. The **bow-pencil** and **bow-pen,** shown in Fig. 13, are convenient for describing small circles. The two points of the instruments must be adjusted to the same length; otherwise, very small circles cannot be drawn. To open or close either of these instruments, support it in a vertical

position by resting the needle point on the paper and bearing slightly on the top of it with the forefinger of one hand, and turn the adjusting nut with the thumb and middle finger of the same hand.

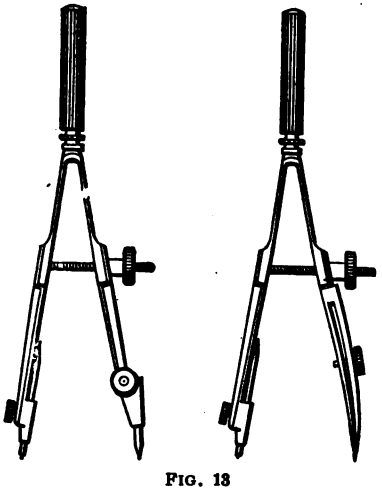
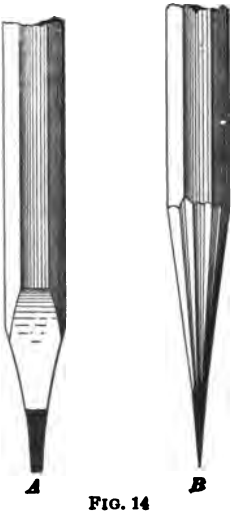


FIG. 13

12. Drawing Paper and Pencils.—The drawing paper recommended for this series of lessons is T. S. Co.'s cold-pressed demy, the size of which is 15″ × 20″. It takes ink well and withstands considerable erasing. The paper is secured to the drawing board by means of **thumbtacks.** Four are usually sufficient—one at each corner of the sheet (see Fig. 7). Place a piece of paper on the drawing board, and press a thumbtack through one of the corners about ¼ or ⅜ of an inch from each edge. Place the T square in position for drawing a horizontal line, as before explained, and straighten the paper so that its upper edge will be parallel to the edge of the T-square blade Pull the corner diagonally opposite that in which the thumbtack was placed, so as to stretch the paper slightly, and push in another thumbtack. Do the same with the remaining two corners. For drawing in pencil, an HHHH pencil of any reputable make should be used The pencil should be sharpened as shown at *A*, Fig. 14. Cut the wood away so as to leave about ¼ or ⅜ of an inch of the lead projecting; then sharpen it flat by rubbing it against a fine file or a piece of



A *B*

FIG. 14

fine emery cloth or sandpaper that has been fastened to a flat stick. Grind it to a sharp edge like a knife blade, and round the corners very slightly, as shown in the figure. If sharpened to a round point, as shown at *B*, the point will wear away very quickly and make broad lines; when so sharpened it is difficult to draw a line exactly through a point. The lead for the compasses should be sharpened in the same manner as the pencil, but should have its width narrower. *Be sure that the compass lead is so secured that when circles are struck in either direction, but one line will be drawn with the same radius and center.*

13. Inking.—For drawing ink lines other than arcs of circles, the **ruling pen** (or *right-line pen*, as it is sometimes called) is used. It should be held as nearly perpendicular to the board as possible, with the hand in the position

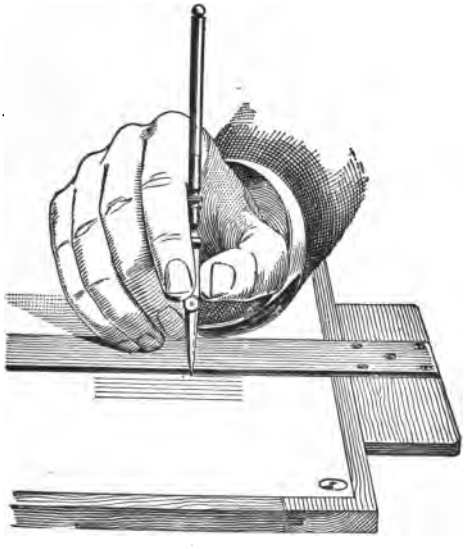


FIG. 15

shown in Figs. 15 and 16, bearing lightly against the T square or triangle, along the edge of which the line is drawn. After a little practice, this position will become natural, and no difficulty will be experienced.

14. The beginner will find that it is not always easy to make smooth lines. If the pen is held so that only one blade bears on the paper when drawing, the line will almost invariably be ragged on the edge where the blade does not bear. When held at right angles to the paper, as in Fig. 16, however, both blades will rest on the paper, and if the pen is in good condition, smooth lines will result. The pen must not be pressed against the edge of the T square or triangle, as the blades will then close together, making the line uneven. The edge should serve as a guide simply.

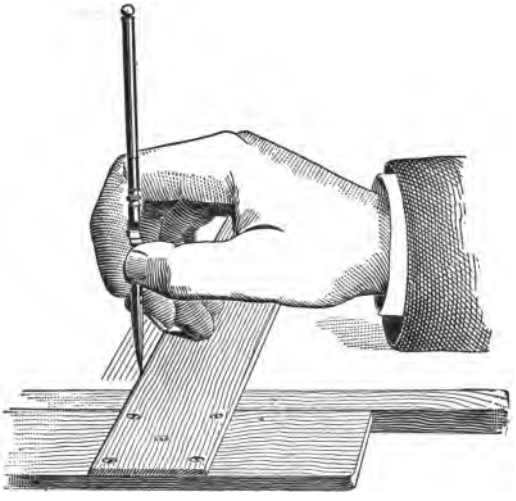


FIG. 16

In drawing circles with the compass pen, the same care should be taken to keep the blades perpendicular to the paper by means of the adjustment at the joint. In both the ruling pen and compass pen, the width of the lines can be altered by means of the screw which holds the blades together. The handles of most ruling pens can be unscrewed, and are provided with a needle point intended for use when copying maps by pricking through the original and the underlying paper, thus locating a series of points through which the outline may be drawn.

15. Drawing Ink.—The ink we recommend for the work in this Course is the T. S. Co.'s superior waterproof liquid India ink. A quill is attached to the cork of every bottle of this ink, by means of which the pen may be filled. Dip the quill into the ink and then pass the end of it between the blades of the drawing pen. Do not put too much ink in the pen, not more than enough to fill it for a quarter of an inch along the blades, otherwise the ink is liable to drop. Many draftsmen prefer to use stick India ink; and for some purposes this is to be preferred to the prepared liquid ink recommended above. In case the stick ink is bought, put enough water in a shallow dish (a common individual butter plate will do) to make enough ink for the drawing, then place one end of the stick in the water, and grind by giving the stick a circular motion. Do not bear hard upon the stick. Test the ink occasionally to see if it is black. Draw a fine line with the pen and hold the paper in a strong light. If it shows brown (or gray), grind a while longer, and test again. Keep grinding until a fine line shows *black*, which will usually take from fifteen minutes to half an hour, depending on the quantity of water used. The ink should always be kept well covered with a flat plate of some kind, to keep out the dust and prevent evaporation. The drawing pen may be filled by dipping an ordinary writing pen into the ink and drawing it through the blades, as previously described when using the quill. If liquid ink is used, all the lines on all the drawings will be of the same color, and no time will be lost in grinding. If stick ink is used, it is poor economy to buy a cheap stick. A small stick of the best quality, costing, say, a dollar, will last as long, perhaps, as five dollars' worth of liquid ink. The only reason for using liquid ink is that all lines are then sure to be of equal blackness and time is saved in grinding.

India ink will dry quickly on the drawing, which is desirable, but it also causes trouble by drying between the blades and refusing to flow, especially when drawing fine lines. *The only remedy is to wipe out the pen frequently* with a cloth. Do not lay the pen down for any great length of time when

it contains ink; wipe it out first. The ink may sometimes be started by moistening the end of the finger and touching it to the point, or by drawing a slip of paper between the ends of the blade. *Always keep the bottle corked.*

16. To Sharpen the Drawing Pen.—When the ruling, or compass, pen becomes badly worn, it must be sharpened. For this purpose a fine oilstone should be used. If an oilstone is to be purchased, a small, flat, close-grained stone should be obtained, those having a triangular section being preferable, as the narrow edge can be used on the inside of the blades in case the latter are not made to swing apart so as to permit the use of a thicker edge.

The first step in sharpening is to screw the blades together, and, holding the pen perpendicular to the oilstone, to draw it back and forth over the stone, changing the slope of the pen from downwards and to the right to downwards and to the left for each movement of the pen to the right and left. The object of this is to bring the blades to exactly the same length and shape, and to round them nicely at the point.

This process, of course, makes the edges even duller than before. To sharpen, separate the points by means of the screw, and rub one of the blades to and from the operator in a straight line, giving the pen a slight twisting motion at the same time, and holding it at an angle of about 15° with the face of the stone. Repeat the process for the other blade. To be in good condition, the edges should be fairly sharp and smooth, but not sharp enough to cut the paper. *All the sharpening must be done on the outside of the blades.* The inside of the blades should be rubbed on the stone only enough to remove any burr that may have been formed. Anything more than this will be likely to injure the pen. The whole operation must be done very carefully, bearing on lightly, as it is easy to spoil a pen in the process. Examine the points frequently, and keep at work until the pen will draw both *fine* lines and *smooth* heavy lines. Many draftsmen prefer to send the pens to be sharpened to the

dealer who sold them, and who is generally willing to do such sharpening at a trifling cost.

17. Irregular Curves.—Curves other than arcs of circles are drawn with the pencil or ruling pen by means of curved or irregular-shaped rulers, called **irregular curves** (see Fig. 17). A series of points is first determined through which the curved line is to pass. The line is then drawn through these points by using such parts of the irregular curve as will pass through several of the points at once, the curve being shifted from time to time as required.

FIG. 17

It is usually difficult to draw a smooth, continuous curve. The tendency is to make it curve out too much between the points, thus giving it a wavy appearance, or else to cause it to change its direction abruptly where the different lines join, making angles at these points. These defects may largely be avoided by always fitting the curve to at least three points, and, when moving it to a new position, by setting it so that it will coincide with part of the line already drawn. It will be found to be a great help if the line be first sketched in freehand, in pencil. It can then be penciled over neatly, or inked, without much difficulty, with the aid of the irregular curve, since the original pencil line will show the general direction in which the curve should be drawn. Whenever the given points are far apart, or fall in such positions that the irregular curve cannot always be made to pass through three of them, the line must invariably be sketched in at first.

As an example, let it be required to draw a curved line through the points *a*, *b*, *c*, *d*, etc., Fig. 18. As just stated, a part of the irregular curve must be used which will pass through at least three points. With the curve set in the first position *A*, its edge is found to coincide with four points

a, *b*, *c*, and *d*. The line may then be drawn from *a* around to *d*, or, better, to a point between *c* and *d*, since, by not continuing it quite to *d*, there is less liability of there being an angle where the next section joins on. For the next section of the line, the curve should be adjusted so as to coincide with a part of the section already drawn; that is, instead of adjusting it to points *d*, *e*, *f*, etc., it should be placed so as to

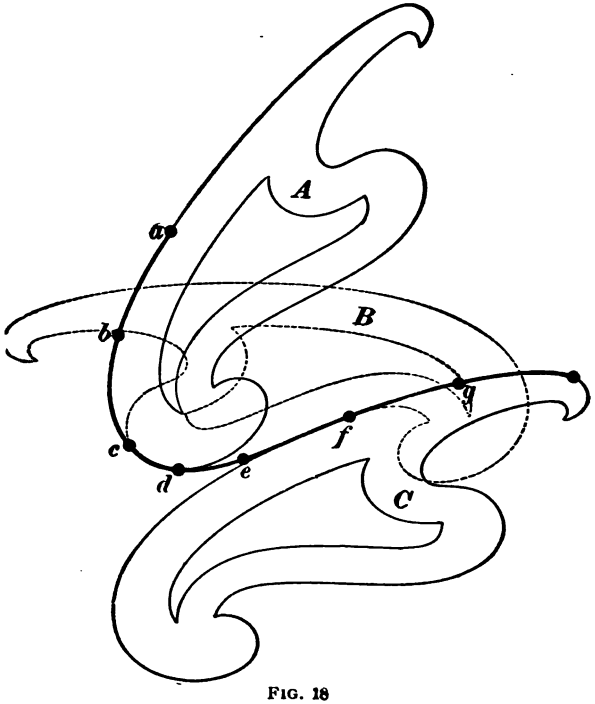


FIG. 18

pass through the point *c*, the part from *c* to *d* being coincident with the corresponding part of the first line drawn. The irregular curve is shown dotted in this position at *B*. Its edge passes through four points *c*, *d*, *e*, and *f*, and the line should be made to stop midway between the last two, as before.

Now, it will be noticed that the points *f* and *g* are so situated that the remainder of the line must curve up, instead of down, as heretofore, the change in curvature occurring at a

point between *e* and *f*. In this case, therefore, it is not necessary for the curve to extend back to *e*, through which point the line has already been drawn, but it may be placed in position *C* with its edge just tangent to the line at the point where the curvature changes.

It is to be noticed that in inking with the irregular curve, the blades of the pen must be kept tangent to its edge (i. e., the inside flat surface of the blades must have the same direction as the curve at the point where the pen touches the paper), which requires that the direction of the pen be continually changed.

18. The **scale** is used for obtaining measurements for drawings. The most convenient forms are the usual flat and triangular boxwood scales, having beveled edges, each of which is graduated for a distance of 12 inches. The beveled edges serve to bring the lines of division close to the paper when the scale is lying flat, so that the drawing may be accurately measured, or distances laid off correctly. The use of the graduations on scales will be explained when it is necessary to use the scale.

19. A **protractor** is shown in Fig. 19. The outer edge is a semicircle, with center at *O*, and is divided into

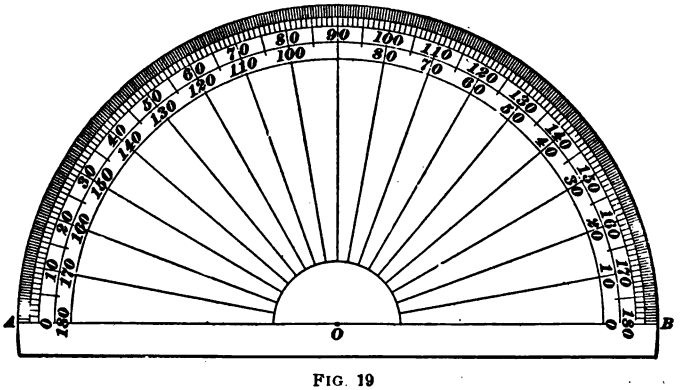


FIG. 19

360 parts. Each division is one-half of one degree, and, for convenience, the degrees are numbered from 0° to 180° from

both A and B. The protractor is used for laying off or measuring angles. Protractors are often made of metal, in which case the central part is cut away to make the drawing under it visible. When using the protractor, it must be placed so that the line OB, Fig. 19, will coincide with the line forming one side of the angle to be laid off or measured, and the center O must be at the vertex of the angle.

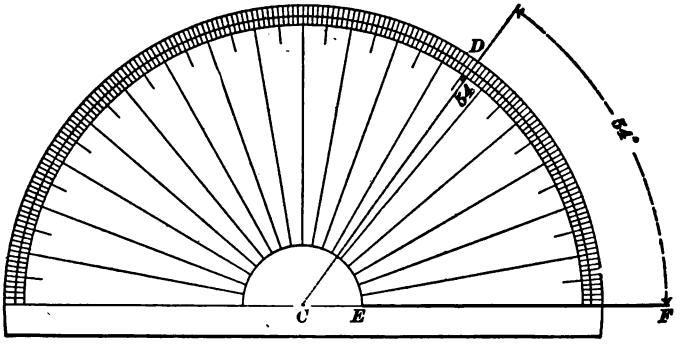


FIG. 20

For example, let it be required to draw a line through the point C, making an angle of 54° with the line EF, Fig. 20. Place the protractor upon the line EF, as just described, with the center O upon the point C. With a sharp-pointed pencil, make a mark on the paper at the 54° division, as indicated at D. A line drawn through C and D will then make an angle of 54° with EF. Greater exactness will be secured if the line EF be extended to the left, so that both zero marks (A and B, Fig. 19) can be placed on the line. This should always be done when possible.

LETTERING

20. In mechanical drawing, all headings, explanatory matter, and dimensions should be neatly printed on the drawing. Ordinary script writing is not permissible.

It is usually difficult for beginners to letter well, and unless the student is skilful at it, he should devote some time to practicing lettering before commencing the drawing. In correcting the plates, the lettering will be considered as well as the drawing. Many students think that it is only necessary to exercise special care when drawing the views on a plate, and that it is not necessary to take particular pains in lettering. This, however, is not the case, for, no matter how well the views may be drawn, if the lettering is poorly done, the finished drawing will not have a neat appearance. In fact, generally speaking, more time is required to make well-executed letters than to make well-executed drawings of objects. We earnestly request the student to practice lettering, and not to think that that part of the work is of no importance. The student should not be too hasty in doing the lettering. It takes an experienced draftsman considerable time to do good lettering, and no draftsman can perform this work as quickly as he can ordinary writing; therefore, no beginner should attempt to do what experienced draftsmen cannot do. In order to letter well, the work must be done slowly. Very frequently more time is spent in lettering a drawing than in inking in the objects represented. Instructions will be given in two styles of freehand lettering, both extensively used in American drafting rooms.

With the exception of the large headings or titles of the plates, the style and size of all lettering used on the original drawing plates of this Course are shown in Fig. 21. This

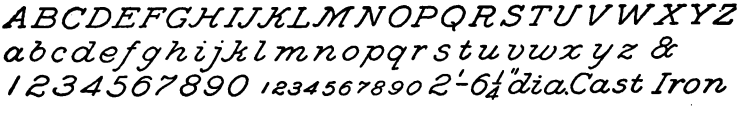


FIG. 21

style, although a little more elaborate and difficult in execution, was selected on account of its greater neatness and legibleness. The two styles are very similar in the formation of the letters, and although the student is advised to

select and use only one of the two on his drawings in this Course, he will find, after having mastered one of the styles, little difficulty in practicing the other.

When lettering, a Gillott's No. 303 pen should be used. The height of the capital letters should be $\frac{3}{32}$", and of the small letters two-thirds of this, or $\frac{1}{16}$". This applies to both styles of freehand lettering. *Do not make them larger than this.*

21. Before beginning to letter, horizontal guide lines should be drawn with the T square, to serve as a guide for the tops and bottoms of the letters (see Fig. 22). The outside lines should be $\frac{3}{32}$" apart for the capitals, and the two lower lines $\frac{1}{16}$" apart for the small letters. The letters should be made to extend fully up to the top, and down to the bottom, guide lines. They must not fall short of the guide lines, nor extend beyond them. Failure to observe this point will cause the lettering to look ragged, as in the second word in Fig. 22.

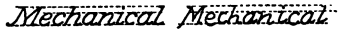


FIG. 22

22. It is very important that all the letters have the same inclination. For example, by referring to Fig. 23 (*a*), it will be seen that the backs of letters like *B*, *E*, *l*, *g*, *d*, *i*, *t*, etc. are parallel and slant the same way. This is also true of both sides of letters like *H*, *M*, *n*, *u*, *h*, *y*, etc. To aid in keeping the slant uniform, draw parallel slanting lines across the guide lines with the 60° triangle, as in Fig. 23 (*b*), and, in lettering, make the backs or sides of the letters parallel with these lines.

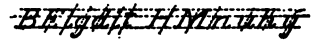


FIG. 23 (*a*)

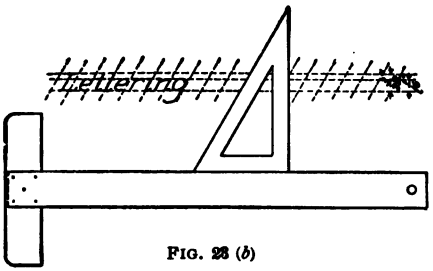


FIG. 23 (*b*)

23. A few points regarding the construction of the letters are illustrated in Fig. 24, in which the letters are shown upon an enlarged

scale. The capital letters *A*, *V*, *Y*, *M*, and *W* must be printed so that their general inclination will be the same as for the other letters. To print the *A*, draw the center line *a d*, having the common slant; from *a* draw the sides *a c* and *a b*, so that points *c* and *b* will each be $\frac{3}{64}$″ distant from point *d*. The side *a b* will be nearly perpendicular to the guide lines. The *V* is like an inverted *A*, and is drawn in the same way, the line *b d* being nearly perpendicular.

To make the *Y*, draw the center line *a d*, having the common slant, which gives the slant for the base of the letter. The upper part of the *Y* begins a little below its center, and is similar to the *V*, though somewhat narrower, as the letter should be only $\frac{5}{64}$″ wide at the top. Points *b* and *c* should be at equal distances from point *a*.

The two sides *b c* and *e f* of the *M* are parallel, and have the common slant. The *M* is made as broad as it is high, or $\frac{3}{32}$″. Having drawn the two sides, mark the point *d*, midway between the points *c* and *f*, and connect it with points *b* and *e*. The lines *b d* and *e d* should be slightly curved, as shown.

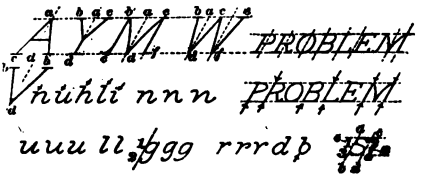


FIG. 24

In the *W* the two outside lines are not parallel, as in the *M*, but are farther apart at the top than at the bottom. Draw the line *a d*, having the common slant. Mark points *b* and *c*, which are exactly $\frac{1}{32}$″ from the point *a*. From *b* and *c*, draw lines *b d* and *c d*. The other half of the *W* is like the first part, *c f* being parallel to *b d* and *e f* parallel to *c d*. It will be seen that the *W* is composed of two narrow *V*'s each $\frac{1}{16}$″ wide, the width of the whole letter being $\frac{1}{8}$″.

24. Capital letters like *P*, *R*, *B*, *L*, *E*, etc. should be printed so that their top and bottom lines will be *exactly horizontal*. This is illustrated in the two examples of the word *problem* in Fig. 24. In the first example, it will be noticed that the tops of the *P* and *R*, the bottom of the *L*,

and the tops and bottoms of the *B* and *E*, all run in the same direction as the guide lines, and coincide with them. In the second example, these lines are not horizontal, which makes the word look very uneven. It is also to be noticed that these lines extend beyond the upright lines in the first word, and that cross-lines are used on the bottom of the *P* and *R*, on the top of the *L*, and on the *M*. In the second word, these lines are omitted at the points indicated by the arrows. These features are found on most of the other capitals.

The small letters *n*, *u*, *h*, *l*, *i*, etc. should have sharp corners at the points indicated by the arrows in Fig. 24. They look much better that way, and are less difficult to make, than when they have round corners. Following these letters are five groups of letters containing *n*, *u*, *l*, *g*, and *r*. The first letter of each group is printed correctly, while the letters following show ways in which they should *not* be printed. In the case of the *g*, point *2* should fall in a slanting direction under point *1*, the slant being the same as *a d* of the preceding letters. The difference between *d* and *b* and the construction of the *s* are also shown in the same figure. The *b* should be made rounding at the point indicated. As a guide in making the *s*, draw the two lines *a b* and *c d*, having the common slant. The *s* should now be drawn so that it will touch these lines at points *1*, *3*, and *4*, but *not* at point *2*. It will be an additional help if the line *e x* is also drawn as a guide for the middle portion of the *s*; but care should be taken not to have it slant more than shown in the copy.

The letters *a*, *o*, *b*, *g*, etc. should be full and round; do not cramp them. It will be necessary to follow the copy closely until familiar with it. Notice that the figures are not made as in writing, particularly the *6*, *4*, *8*, and *9* (see Fig. 21). Try to space the letters evenly. Letter in pencil first, and, if not right, erase and try again.

25. Another style of freehand lettering is shown in Fig. 25. This style is extensively used for the lettering of

working drawings. It is more easily and rapidly made than the style previously described, and although not productive

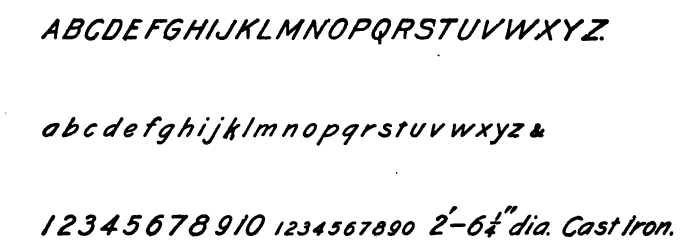


FIG. 25

of as high degree of neatness in appearance will be found very useful and acceptable for general office work.

A comparison between the two systems will disclose a great similarity in the detail formation of the letters.

26. The horizontal and slanting guide lines are drawn exactly in the same manner as for the style previously described, and if not followed, the results will be similar. See the uneven appearance of the second word in Fig. 26.

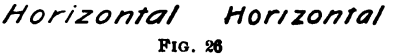


FIG. 26

27. By studying the formation of the letters carefully, it will be found that many of them are formed on the same principle, as shown in Fig. 27.

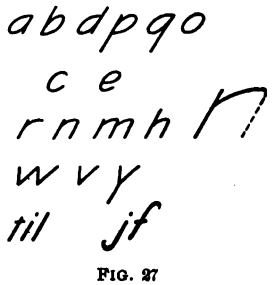


FIG. 27

The ovals of the letters *a*, *b*, *d*, *g*, *p*, and *q* are formed exactly alike and have a slant of 45° with the horizontal. These ovals should be made a little wider at the top than at the bottom. Care should be taken that the straight downward strokes are made parallel to the slanting guide lines. The letters *c* and *e* are commenced in the same way, but the upper loop in *e* should be formed in such a manner that its axis will be at an angle of 45° with the horizontal. The *r* is made by having the down stroke parallel to the slanting guide line

and the up stroke slightly curved in the same way as in the letter *n* (see Fig. 27). The strokes in the letters *j* and *f* are the same, with the position of the hook part reversed.

28. The capital letters shown in Fig. 28 are formed very nearly in the same manner as those shown in Art. **23,** but differ slightly by omitting the short spurs that give to the letters a more finished appearance.

In the capital *M*, however, there is a decided variation. The *M* is made with four strokes, putting in the parallel sides first. The two other strokes should join midway

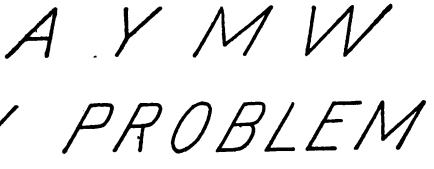


FIG. 28

between these sides and at a distance from the top of about $\frac{1}{5}$ of the height of the letter. These strokes, as will be seen, are straight and not curved.

29. The *numerals* should be $\frac{3}{32}$" high and of the style shown in Fig. 25; fractions should be $\frac{1}{8}$" high over all. In

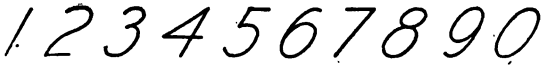


FIG. 29

Fig. 29 the numerals are illustrated to a larger scale, and a comparison with the style shown in Fig. 21 will disclose several variations.

The loops of the *2*, *3*, *5*, *6*, and *9* should be formed so that their axes will be at an angle of 45° with the horizontal. It will be noted that the *7* differs widely from the style shown in Fig. 21, the down stroke not curving but having a straight slant of 45°. The axis of the *0* and the loops of the *8* should slant at an angle of 60°.

Diligent practice for a short time and careful observation of the forms of letters and numerals, as shown in Figs. 21–29, will soon enable the student to acquire skill and speed in this branch of drawing.

30. The alphabet shown in Fig. 30, called the **block letter,** is to be used for the large headings or titles of plates, as shown on the copy plates. This alphabet is *not* to be used on the first five geometrical drawing plates. The letters and figures are to be made $\frac{5}{16}''$ high and $\frac{1}{4}''$ wide, except *M*, which is $\frac{5}{16}''$ wide, and *W*, which is $\frac{3}{8}''$ wide. The thickness of all the lines forming the letters is $\frac{1}{16}''$, measured horizontally. The distance between any two letters of a word is $\frac{1}{16}''$, except where *A* follows *P* or *F*;

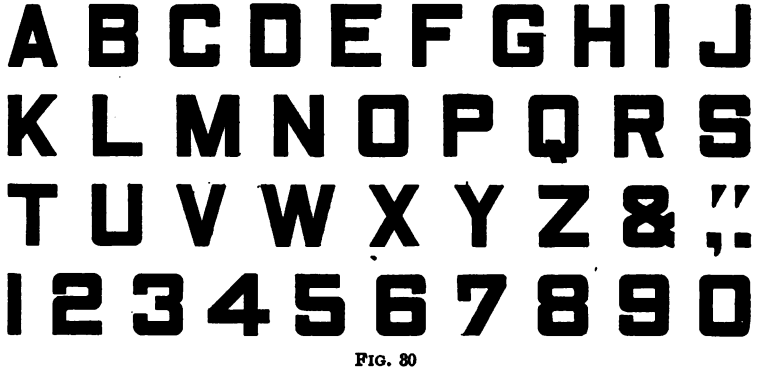


FIG. 30

where *V*, *W*, or *Y* follows *L*; where *J* follows *F*, *P*, *T*, *V*, *W*, or *Y*; where *T* and *A* are adjacent, or *A* and *V*, *W*, or *Y* are adjacent; in this case, the bottom extremity of *A* and the top extremity of *P*, *T*, *V*, *W* are in the same vertical line, etc.

Since these letters are composed of straight lines, they can be made with the T square and triangle. In lettering the title of the drawing plates, the student should draw six horizontal lines $\frac{1}{16}''$ apart in lead pencil, to represent the thickness of the letters at the top, center, and bottom; then, by use of the triangle, he should draw in the width of

the letters and the spaces between them in lead pencil. Having the letters all laid out, he can very easily ink them in. Use the ruling pen for inking in the straight outlines of the letters, and the lettering pen for rounding the corners and filling in between the outlines. It is well to ink in all the perpendicular lines first, next the horizontal lines, and then the oblique lines.

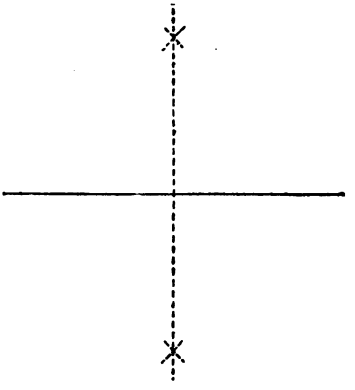
PLATES

31. Preliminary Directions.—The size of each plate over all will be 14″ × 18″, having a border line ½″ from each edge all around, thus making the size of the space on which the drawing is to be made 13″ × 17″. The sheet itself must be larger than this when first placed upon the board, so that the thumbtack holes may be cut out; the extra margin is also very convenient for testing the pen, in order to see whether the ink is flowing well and whether the lines are of the proper thickness.

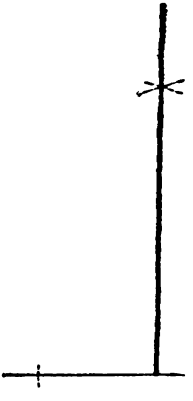
32. The first five plates will consist of practical geometrical problems which constantly arise in practice when making drawings. The method of solving every one of these problems should be carefully memorized, so that they can be instantly applied when the occasion requires, without being obliged to refer to the text for help. Particular attention should be paid to the lettering. Whenever any dimensions are specified, they should be laid off as accurately as possible. All drawings should be made as neat as possible, and the penciling entirely finished before inking in any part of it. Great care should be taken in distributing the different views, parts, details, etc. on the drawing, so that when the drawing is completed, one view will not be so near to another as to mar the appearance of the drawing. The hands should be perfectly clean, and should not touch the paper except when necessary. No lines should be erased except when *absolutely* necessary; for, whenever a line has once been erased, the dirt flying around in the air

PLATE

PROBLEM 1: To bisect a straight line.

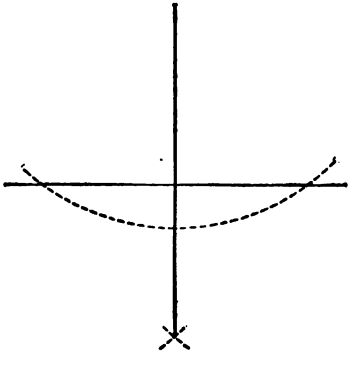


PROBLEM 2: To draw
CAS



PROBLEM 3: To draw a perpendicular to a straight line from a point w
CASE I.

CA



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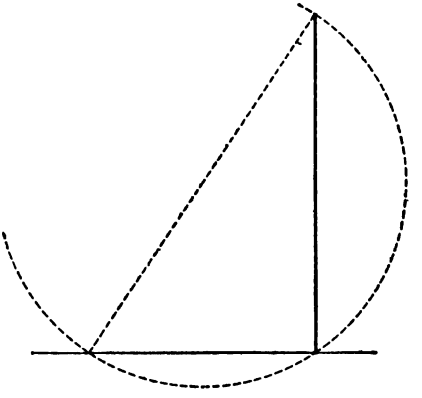
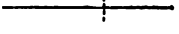
r perpendicular to a straight line from a given point in that line.

I.

CASE II.

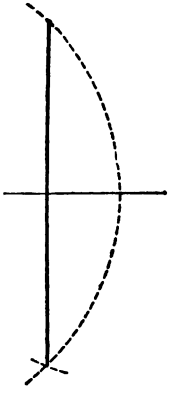


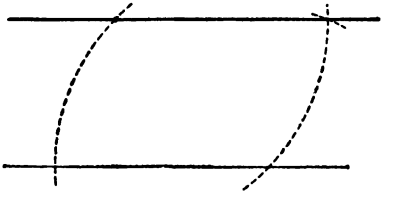


ithout it.

SE II.

PROBLEM 4: Through a given point to draw a straight line parallel to a given straight line.





JOHN SMITH, CLASS Nº 4529.

and constantly falling on the drawing will stick to any spot where an erasure has been made, and it is then very difficult, if not impossible, to entirely remove it. For this reason, all construction lines that are to be removed, or that are liable to be changed, should be drawn lightly, that the finish of the paper may not be destroyed when erasing them. When it is found necessary to erase an ink blot or a line that has been inked in, only an *ink eraser* or *sand rubber* should be used. After the erasure has been made, the roughened part of the surface of the paper can be smoothed by rubbing with some hard, smooth substance, as a piece of ivory or the handle of a knife.

PLATE I

33. Take a sheet of drawing paper 15″ wide and 20″ long (demy size), and fasten it to the board as previously described. On this draw the outlines of the size of the plate, 14″ × 18″, and draw the border line all around ½″ from the edge of the outline, leaving the space inside for the drawing 13″ × 17″. When the word *drawing* is used hereafter, it refers only to the space inside the border lines and the objects drawn upon it. To understand clearly what follows, refer to Plate I. Divide the drawing into two equal parts by means of a faint horizontal line. This line is shown dotted in Plate I, above referred to. Divide each of these halves into three equal parts, as shown by the dotted lines; this divides the drawing into six rectangular spaces. *These division lines are not to be inked in, but must be erased when the plate is completed.* On the first five plates, space for the lettering must be taken into account. For each of the six equal spaces, the lettering will take up one or two lines. The height of all capital letters on these plates will be $\frac{3}{32}$″, and of the small letters $\frac{2}{3}$ of this, or $\frac{1}{16}$″. The distance between any two lines of lettering will also be $\frac{3}{32}$″. The distance between the tops of the letters on the first line of lettering and the top line of the equal divisions of

the drawing is to be $\frac{1}{2}''$; and the space between the bottoms of the letters and the topmost point of the figure represented on the drawing within one of these six divisions must also be not less than $\frac{1}{2}''$. This makes a very neat arrangement, if the figure is so placed that the outermost points of the bounding lines are equally distant from the sides of one of the equal rectangular spaces. Consequently, if there is one line of lettering, no point of the figure drawn should come nearer than $\frac{1}{2}'' + \frac{3}{32}'' + \frac{1}{2}'' = 1\frac{3}{32}''$ to the top line of the space within which it is represented; or, if there are two lines of lettering, nearer than $\frac{1}{2}'' + \frac{3}{32}'' + \frac{3}{32}'' + \frac{3}{32}'' + \frac{1}{2}'' = 1\frac{9}{32}''$. The letter heading for each figure on the first five plates will be printed in heavy-faced type at the beginning of the directions explaining each problem. The student must judge for himself by the length of the heading whether it will take up one line or two, and make due allowance for the space it takes up. This is a necessary precaution, because the lettering should never be done until the rest of the drawing is entirely finished and inked in.

PROBLEM 1.—**To bisect a straight line.**

See Fig. 31; also 1 of Plate I.

CONSTRUCTION. — Draw a straight line AB, $3\frac{1}{2}''$ long. With one extremity A as a center, and a radius greater than one-half of the length of the line, describe an arc of a circle on each side of the given line; with the other extremity B as a center, and the same radius, describe arcs intersecting the first two in the points C and D. Join C and D by the line CD, and the point P, where it intersects AB, will be the required point; that is, $AP = PB$, and P is the middle point

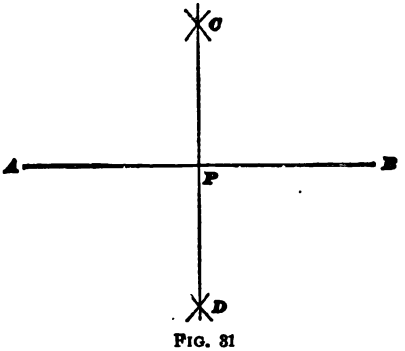


FIG. 31

of AB. Since CD is perpendicular to AB, this construction also gives a *perpendicular to a straight line at its middle point.*

PROBLEM 2.—**To draw a perpendicular to a straight line from a given point in that line.**

NOTE.—As there are two cases of this problem, requiring two figures on the plate, the line of letters will be run clear across both figures, as shown in Plate I.

Case I.—*When the point is at or near the center of the line.* See Fig. 32; also 2, Case I, of Plate I.

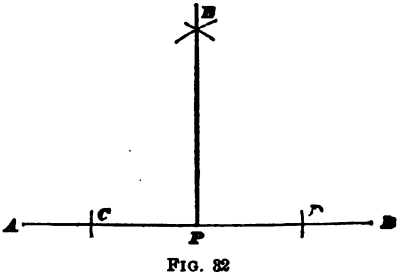


FIG. 32

CONSTRUCTION. — Draw AB $3\frac{1}{2}''$ long. Let P be the given point. With P as a center, and any radius, as PD, describe two short arcs cutting AB in the points C and D. With C and D as centers, and any convenient radius greater than PD, describe two arcs intersecting in E. Draw PE, and it will be perpendicular to AB at the point P.

Case II.—*When the point is near the end of the line.* See Fig. 33; also 2, Case II, of Plate I.

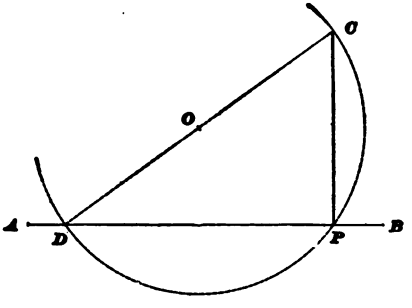


FIG. 33

Draw AB $3\frac{1}{2}''$ long. Take the given point P about $\frac{3}{8}''$ from the end of the line. With any point O as a center, and a radius OP, describe an arc cutting AB in P and D. Draw DO, and prolong it until it intersects the arc in the point C. A line drawn through C and P will be perpendicular to AB at the point P.

PROBLEM 3.—**To draw a perpendicular to a straight line from a point without it.**

As in Problem 2, there are two cases.

Case I.—*When the point lies nearly over the center of the line.* See Fig. 34; also 3, Case I, of Plate I.

CONSTRUCTION.—Draw AB $3\frac{1}{2}''$ long. Let P be the given point. With P as a center, and any radius PD greater than the distance from P to AB, describe an arc cutting AB in C and D. With C and D as centers, and any convenient radius, describe short arcs intersecting in E. A line drawn through P and E will be perpendicular to AB at F.

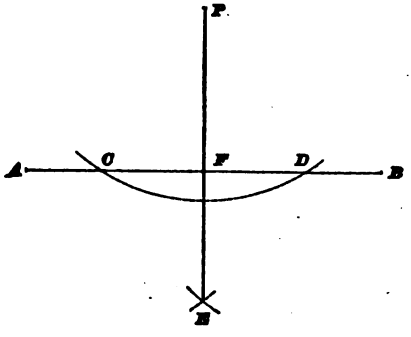


FIG. 34

Case II.—*When the point lies nearly over one end of the line.* See Fig. 35; also 3, Case II, of Plate I.

Draw AB $3\frac{1}{2}''$ long, and let P be the given point. With any point C on the line AB as a center, and the distance CP as a radius, describe an arc PED cutting AB in E. With E as a center, and the distance EP as a radius, describe an arc cutting the arc PED in D. The line joining the points P and D will be perpendicular to AB.

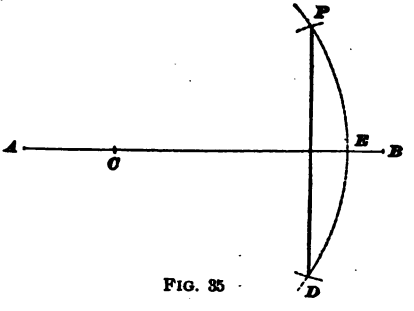


FIG. 35

PROBLEM 4.—**Through a given point, to draw a straight line parallel to a given straight line.**

See Fig. 36; also 4 of Plate I.

CONSTRUCTION.—Let P be the given point, and AB the given straight line $3\frac{1}{2}''$ long. With P as a center, and any

convenient radius, describe an arc CD intersecting AB in D. With D as a center, and the same radius, describe the arc PE. With D as a center, and a radius equal to the chord of the arc PE, describe an arc intersecting CD in C. A straight line drawn through P and C will be parallel to AB.

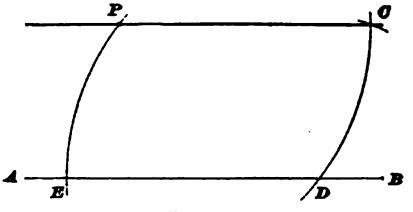


FIG. 36

34. These four problems form Plate I. They should be carefully and accurately drawn in with lead-pencil lines and then inked in. It will be noticed that on Plate I, and Figs. 31 to 36, the given lines are *light*, the required lines *heavy*, and the construction lines, which in a practical working drawing would be left out, are *light dotted*. This system must also be followed in the four plates which are to follow. A single glance enables one to see at once the reason for drawing the figure, and the eye is directed immediately to the required line.

In the first five plates, accuracy and neatness are the main things to be looked out for. The student should be certain that the lines are of *precisely* the length that is specified in the description. When drawing a line through two points, be sure that the line goes through the points; if it does not pass exactly through the points, erase it and draw it over again. If a line is supposed to end at some particular point, make it end there—do not let it extend beyond or fall short. Thus, in Fig. 36, if the line PC does not pass through the points P and C, it is not parallel to AB. By paying careful attention to these points, the student saves himself a great deal of trouble in the future. *Do not hurry your work.*

First ink in all of the light lines and light dotted lines (which have the same thickness); then ink in the heavy required lines after the pen has been readjusted. Now do the lettering (first read carefully the paragraphs under the head "Lettering"), and finally draw the heavy border lines,

which should be thicker than any other line on the drawing. The word "Plate" and its number should be printed at the top of the sheet, outside the border lines, and midway of its length, as shown. The student's name, followed by the words "Class" and "No.," and after this his Course letter and *class number* should be printed in the lower right-hand corner below the border line, as shown. Thus, John Smith, Class No. C 4529. The date on which the drawing was completed should be placed in the lower left-hand corner, below the border line. *All of this lettering is to be in capitals* $\frac{3}{32}$*" high.* Erase the division lines, and clean the drawing by rubbing very gently with the eraser. Care must be exercised when doing this, or the inked lines will also be erased. It is best to use a so-called "Sponge Rubber" for this purpose, as it will not injure the inked lines. *If any part of a line has been erased or weakened, it must be redrawn.* Then write with the lead pencil your name and address in full on the back of your drawing, after which put your drawing in the empty tube which was sent you, and send it to the Schools.

HINTS FOR PLATE I

35. *Do not forget to make a distinction between the width of the given and required lines, nor forget to make the construction lines dotted.*

When drawing dotted lines, take pains to have the dots and spaces uniform in length. Make the dots about $\frac{1}{16}$*" long and the spaces only about one-third the length of the dots.*

Try to get the work accurate. The constructions must be accurate, and all lines or figures should be drawn of the length or size previously stated. To this end, work carefully and keep the pencil leads very sharp, so that the lines will be fine.

The lettering on the first few plates, as well as on the succeeding plates, is fully as important as the drawing, and should be done in the neatest possible manner. Drawings sent in for correction with the lettering omitted will be returned for completion.

The reference letters like A, B, C, etc., as shown in Fig. 31, are not to be put on the plates.

Do not neglect to trim the plates to the required size. Do not punch large holes in the paper with the dividers or compasses. Remember that the division lines are to be erased—not inked in

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PLATE II

36. Draw the division lines in the same manner as described for Plate I. The following five problems (5 to 9, inclusive) are to be drawn in regular order, as was done in Plate I, with problems from 1 to 4. The letter headings are given in heavy-faced type after the problem number.

PROBLEM 5.—**To bisect a given angle.***

Case I.—*When the sides intersect within the limits of the drawing.* See Fig. 37.

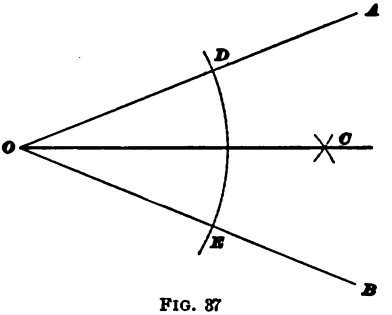


FIG. 37

CONSTRUCTION. — Let AOB be the angle to be bisected. Draw the sides OA and OB $3\frac{1}{2}''$ long. With the vertex O as a center, and any convenient radius, describe an arc DE intersecting OA at D and OB at E. With D and E as centers, and a radius greater than the chord of half the arc DE, describe two arcs intersecting at C. The line drawn through C and O will bisect the angle; that is, $AOC = COB$.

Case II.—*When the sides do not intersect within the limits of the drawing.* See Fig. 38.

CONSTRUCTION.—Draw two lines, AB and CD, each $3\frac{1}{2}''$ long, and inclined towards each other as shown. With any

* Since the letter heading in this problem is very short, it will be better to place it over each of the two cases separately, instead of running it over the division line, as was done with the long headings of the two cases in Plate I. Put Case I and Case II under the heading, as in the previous plate.

point E on CD as a center and any convenient radius, describe arc $FIGH$; with G as a center and same radius, describe arc $HLEF$, intersecting $FIGH$ in H and F. With L as a center and same radius, describe arc KGJ· with I as

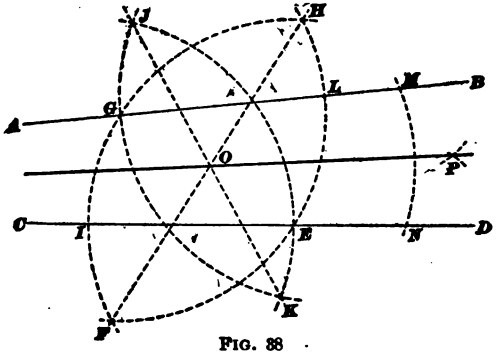


FIG. 38

a center and same radius, describe arc JEK, intersecting KGJ in K and J. Draw HF and JK; they intersect at O, a point on the bisecting line. With O as a center and the same or any convenient radius, describe an arc intersecting AB and CD in M and N. With M and N as centers and any radius greater than one-half MN, describe arcs intersecting at P. A line drawn through O and P is the required bisecting line.

PROBLEM 6.—**To divide a given straight line into any required number of equal parts.**

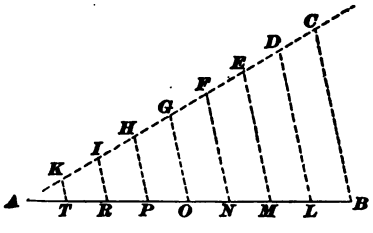


FIG. 39 (*a*)

See Fig. 39 (*a*).

CONSTRUCTION. — AB is the given line $3\frac{7}{16}$" long. It is required to divide it into eight equal parts. Through one extremity A of the line, draw an indefinite straight line AC, making any angle with AB. Set the dividers to any convenient distance, and space off eight equal divisions on AC, as AK, KI, IH, etc. Join C and B by the

straight line $C B$, and through the points D, E, F, G, etc. draw lines $D L$, $E M$, etc. parallel to $C B$, by using the two triangles; these parallels intersect $A B$ in the points L, M, N, etc., which are equally distant apart. The spaces $L M$, $M N$, $N O$, etc. are each equal to $\frac{1}{8} A B$. Proceed in a similar way for any number of equal parts into which $A B$ is to be divided.

Another method is shown in Fig. 39 (b). Draw $A B$ as before, and erect the perpendicular $B C$. Now divide the length of $A B$ by the number denoting the number of equal parts into which $A B$ is to be divided, obtaining, in this case, $3\frac{7}{16}'' \div 8 = \frac{55}{128}''$. As $A C$ is longer than $A B$, the equal divisions $A K$, $K I$, etc. are longer than $A T$, $T R$, etc. and may be made any convenient length greater than $A B \div 8$. In this case, $\frac{1}{2}''$ is the most convenient fraction nearest to and greater than $\frac{55}{128}''$; hence, consider $A K$, $K I$, etc. to be each $\frac{1}{2}''$ in length, thus making the length of $A C$ $8 \times \frac{1}{2}'' = 4''$. With A as a center and a radius equal to $4''$, describe an arc cutting $B C$ in C, and draw $A C$. Then with a scale lay off $A K = K I =$ etc. $= \frac{1}{2}''$, and project K, I, H, etc. upon $A B$, in T, R, P, etc., the required points. The advantage of this method over the other is that the T square and triangle can be used throughout, thus making it very much easier to draw the parallels $D L$, $E M$, etc.

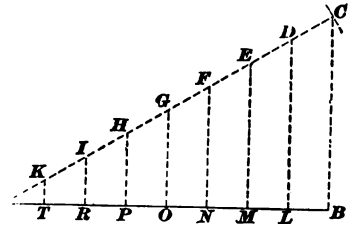


FIG. 39 (b)

The student, when drawing this plate, is at liberty to use either of the two methods given in this problem.

PROBLEM 7.—**To draw a straight line through any given point on a given straight line to make any required angle with that line.**

CONSTRUCTION.—In Fig. 40, $A B$ is the given line $3\frac{1}{2}''$ long, P is the given point, and $E O F$ is the given angle. With the vertex O as a center, and any convenient radius, describe

an arc EF cutting OE and OF in E and F. With P as a center, and the same radius, describe an arc CD. With D as a center, and a radius equal to the chord of the arc EF, describe an arc cutting CD in C. A line drawn through the points P and C will make an angle with AB equal to the angle O, or $CPD = EOF$.

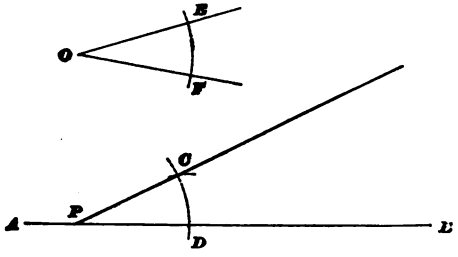


FIG. 40

PROBLEM 8.—**To draw an equilateral triangle, one side being given.**

CONSTRUCTION.—In Fig. 41, AB is the given side $2\frac{1}{2}$" long. With AB as a radius, and A and B as centers, describe two arcs intersecting in C. Draw CA and CB, and CAB is an equilateral triangle.

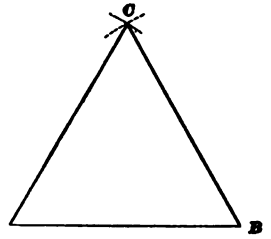


FIG. 41

PROBLEM 9.—**The altitude of an equilateral triangle being given, to draw the triangle.**

CONSTRUCTION.—In Fig. 42, AB is the altitude $2\frac{1}{4}$" long. Through the extremities of AB draw the parallel lines CD and EF perpendicular to AB. With B as a center, and any convenient radius, describe the semicircle $CHKD$ intersecting CD in C and D. With C and D as centers, and the same radius, describe arcs cutting the semicircle in H and K. Draw BH and BK, and prolong them to meet EF in E and F. BEF is the required equilateral triangle.

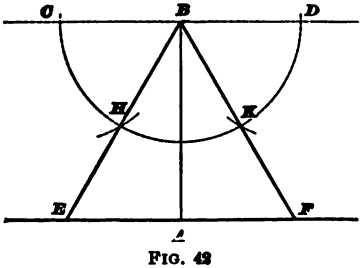


FIG. 42

This problem finishes Plate II. The directions for inking in, lettering, etc. are the same as for Plate I.

PLATE III

37. This plate is to be divided up like Plates I and II and the six following problems are to be drawn in a similar manner:

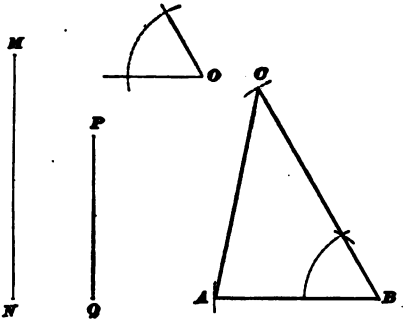


FIG. 43

PROBLEM 10.—**Two sides and the included angle of a triangle being given, to construct the triangle.**

CONSTRUCTION.—In Fig. 43, make the given sides MN $2\frac{1}{2}''$ long and PQ $1\frac{7}{8}''$ long. Let O be the given angle. Draw AB, and make it equal in length to PQ. Make the angle CBA equal to the given angle O, and make CB equal in length to the line MN. Draw CA, and CAB is the required triangle.

PROBLEM 11.—**To draw a parallelogram when the sides and one of the angles are given.**

CONSTRUCTION.—In Fig. 44, make the given sides MN $2\frac{1}{2}''$ long and PQ $1\frac{7}{8}''$ long. Let O be the given angle. Draw AB equal to MN, and draw BC, making an angle with AB equal to the given angle O. Make BC equal to PQ. With C as a center, and a radius equal to MN, describe an arc at D. With A as a center, and a radius equal to PQ, describe an arc intersecting the other arc in D. Draw AD and CD, and $ABCD$ is the required parallelogram.

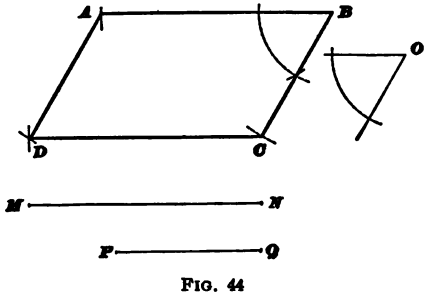


FIG. 44

PROBLEM 12.—**An arc and its radius being given, to find the center.**

CONSTRUCTION.—In Fig. 45, $A\,C\,D\,B$ is the arc, and $M\,N$, $1\frac{3}{4}''$ long, is the radius. With $M\,N$ as a radius, and any point C in the given arc as a center, describe an arc at O. With any other point D in the given arc as a center, and the same radius, describe an arc intersecting the first in O. O is the required center.

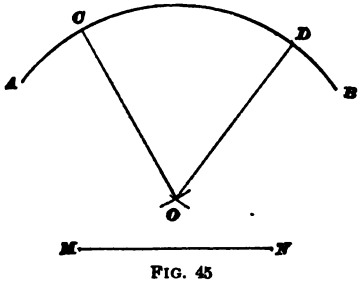


FIG. 45

PROBLEM 13.—**To pass a circumference through any three points not in the same straight line.**

CONSTRUCTION.—In Fig. 46, A, B, and C are the given points. With A and B as centers, and any convenient radius, describe arcs intersecting each other in K and I. With B and C as centers, and any convenient radius, describe arcs intersecting each other in D and E. Through I and K and through D and E, draw lines intersecting at O. With O as a center, and $O\,A$ as a radius, describe a circle; it will pass through A, B, and C.

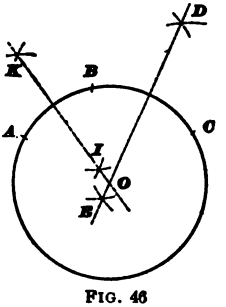


FIG. 46

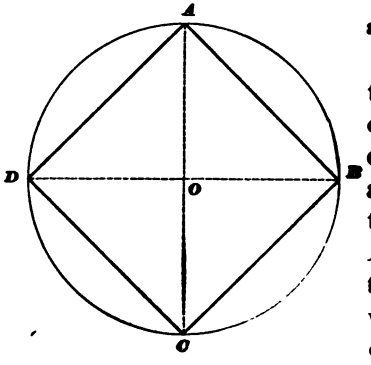


FIG. 47

PROBLEM 14.—**To inscribe a square in a given circle.**

CONSTRUCTION.—In Fig. 47, the circle $A\,B\,C\,D$ is $3\frac{1}{2}''$ in diameter. Draw two diameters, $A\,C$ and $D\,B$, at right angles to each other. Draw the lines $A\,B$, $B\,C$, $C\,D$, and $D\,A$, joining the points of intersection of these diameters with the circumference of the circle, and they will be the sides of the square.

PROBLEM 15—**To inscribe a regular hexagon in a given circle.**

CONSTRUCTION.—In Fig. 48, from O as a center, with the dividers set to $1\frac{1}{4}''$, describe the circle $A\,B\,C\,D\,E\,F$. Draw the diameter $D\,O\,A$, and from the points D and A, with the dividers set equal to the radius of the circle, describe arcs intersecting the circle at E, C, F, and B. Join these points by straight lines, and they will form the sides of the hexagon. This problem completes Plate III.

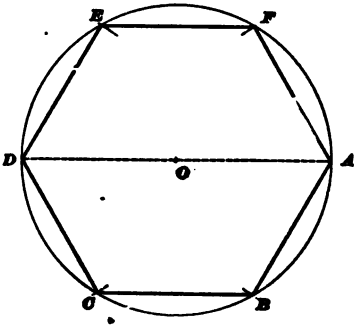


FIG. 48

PLATE IV

38. The first four problems on this plate are more difficult than any on the preceding plates and will require very careful construction. All the sides of each polygon must be of exactly the same length, so that they will space around evenly with the dividers. The figures should not be inked in until the pencil construction is done accurately. The preliminary directions for this plate are the same as for the preceding ones.

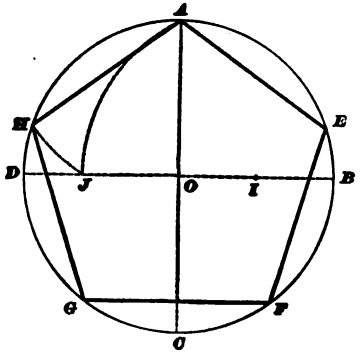


FIG. 49

PROBLEM 16.—**To inscribe a regular pentagon in a given circle.**

CONSTRUCTION.—In Fig. 49, from O as a center, with the dividers set to $1\frac{1}{4}''$, describe the circle $A\,B\,C\,D$. Draw the two diameters $A\,C$ and $D\,B$ at right angles to each other. Bisect one of the radii, as $O\,B$, at I. With I as a center, and $I\,A$ as a radius, describe the arc $A\,J$ cutting $D\,O$ at J.

With A as a center, and $A\,J$ as a radius, describe an arc $J\,H$ cutting the circumference at H. The chord $A\,H$ is one side of the pentagon.

PROBLEM 17.—**To inscribe a regular octagon in a given circle.**

CONSTRUCTION.—In Fig. 50, from O as a center, with the dividers set to $1\frac{3}{4}''$, describe the circle $A\,B\,C\,D\,E\,F\,G\,H$. Draw the two diameters $A\,E$ and $G\,C$ at right angles to each other. Bisect one of the four equal arcs, as $A\,G$ at H, and draw the diameter $H\,O\,D$. Bisect another of the equal arcs, as $A\,C$ at B, and draw the diameter $B\,O\,F$. Straight lines drawn from A to B, from B to C, etc. will form the required octagon.

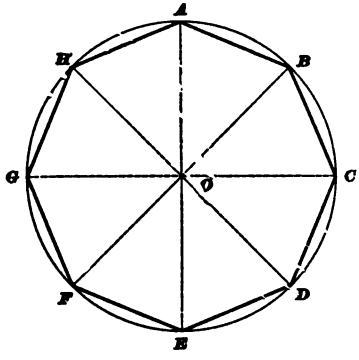


FIG. 50

PROBLEM 18.—**To inscribe a regular polygon of any number of sides in a given circle.**

CONSTRUCTION.—In Fig. 51, from O as a center, with the dividers set to $1\frac{3}{4}''$, describe the circle $A\,7\,C\,D$. Draw the two diameters $D\,7$ and $A\,C$ at right angles to each other. Divide the diameter $D\,7$ into as many equal parts as the polygon has sides (in this case seven). Prolong the diameter $A\,C$ and make $3'A$ equal to three-fourths of the radius $O\,A$. Through $3'$ and 2, the second division from D on the diameter $D\,7$, draw the line $3'I$, cutting the circumference at I. Draw the chord $D\,I$, and it is one side of the required polygon. The others may be spaced off around the circumference.

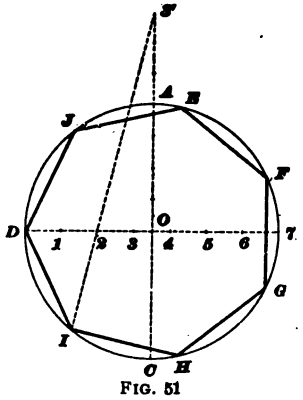


FIG. 51

PROBLEM 19.—**The side of a regular polygon being given, to construct the polygon.**

CONSTRUCTION.—In Fig. 52, let *A C* be the given side. If the polygon is to have eight sides, the line *A C* should be, for this plate, 1¼″ long. Produce *A C* to *B*. From *C* as center, with a radius equal to *C A*, describe the semicircle *A 1 2 3 4 5 6 7 B*, and divide it into as many equal parts as there are sides in the required polygon (in this case eight). From the point *C*, and through the second division from *B*, as *6*, draw the straight line *C 6*. Bisect the lines *A C* and *C 6* by perpendiculars intersecting in *O*. From *O* as a center, and with *O C* as a radius, describe the circle *C A H G F E D 6*. From *C*, and through the points *1*, *2*, *3*, *4*, *5* in the semicircle, draw lines *C H*, *C G*, *C F*, etc., meeting the circumference. Joining the points *6* and *D*, *D* and *E*, *E* and *F*, etc., by straight lines, will complete the required polygon.

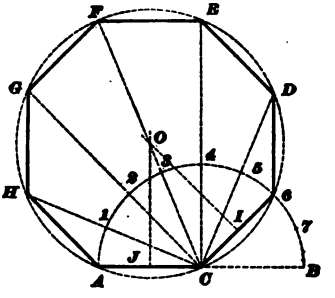


FIG. 52

PROBLEM 20.—**To find an arc of a circle having a known radius, which shall be equal in length to a given straight line.**

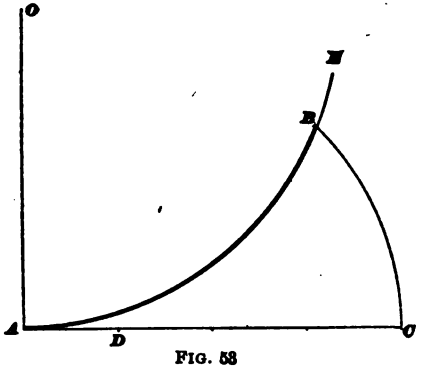


FIG. 53

NOTE.—There is no exact method, but the following approximate method is close enough for all practical purposes, when the required arc does not exceed ⅛ of the circumference.

CONSTRUCTION.—In Fig. 53, let *A C* be the given line 3½″ long. At *A*, erect the perpendicular *A O*, and make it equal in length to the given radius, say 4″ long.

With OA as a radius, and O as a center, describe the arc ABE. Divide AC into four equal parts, AD being the first of these parts, counting from A. With D as a center, and a radius DC, describe the arc CB intersecting ABE in B. The length of the arc AB very nearly equals the length of the straight line AC.

PROBLEM 21.—**An arc of a circle being given, to find a straight line of the same length.**

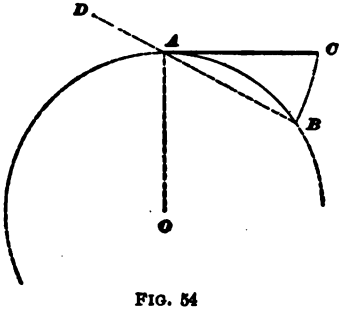


FIG. 54

This is also an approximate method, but close enough for practical purposes, when the arc does not exceed $\frac{1}{6}$ of the circumference.

CONSTRUCTION.—In Fig. 54, let AB be the given arc; find the center O of the arc, and draw the radius OA. For this problem, choose the arc so that the radius will not exceed $1\frac{3}{4}''$. At A, draw AC perpendicular to the radius (and, of course, tangent to the arc). Draw the chord AB, and prolong it to D, so that $AD = \frac{1}{2}$ the chord AB. With D as a center, and a radius DB, describe the arc BC cutting AC in C. AC will be very nearly equal to the arc AB.

PLATE V

39. On this plate there are five problems instead of six It should be divided into six equal parts or divisions, as the previous ones. The two right-hand end divisions are used to draw in the last figure of Plate V, which is too large to put in one division.

PROBLEM 22.—**To draw an egg-shaped oval.**

CONSTRUCTION.—In Fig. 55, on the diameter AB, which is $2\frac{3}{4}''$ long, describe a circle $ACBG$. Through the center O,

draw $O\,C$ perpendicular to $A\,B$, cutting the circumference $A\,C\,B\,G$ in C. Draw the straight lines $B\,C\,F$ and $A\,C\,E$. With B and A as centers, and the diameter $A\,B$ as a radius, describe arcs terminating in D and H, the points of intersection with $B\,F$ and $A\,E$. With C as a center, and $C\,D$ as a radius, describe the arc $D\,H$. The curve $A\,D\,H\,B\,G$ is the required oval.

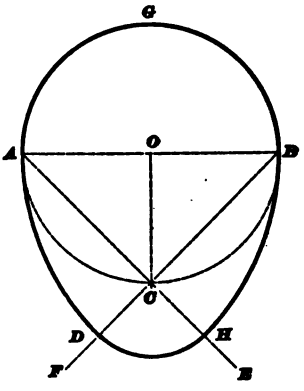


FIG. 55

PROBLEM 23. — **To draw an ellipse, the diameters being given.** The exact method.

CONSTRUCTION.—In Fig. 56, let $B\,D$, the long diameter, or major axis, which is $3\frac{1}{2}''$ long, and $A\,C$, the short diameter, or minor axis, which is $2\frac{1}{4}''$ long, intersect at right angles to each other in the center O, so that $D\,O = O\,B$ and $A\,O = O\,C$. With O as a center, and $O\,C$ as a radius, describe a circle; with the same center, and $O\,D$ as a radius, describe another circle. Divide both circles into the same number of equal parts, as *1–2*, *2–3*, etc. This is best done by first dividing the larger circle into the required number of parts, beginning at the center line $A\,C$, and then drawing radial lines through the points of division on this circle, to the center O of the circles, as shown in the upper right-hand quarter of the figure. The radial lines will divide the smaller circle into the same number of parts that the larger one has been divided into. Through the points of division on the smaller circle, draw horizontal lines, and, through the points of division on the larger circle, draw vertical

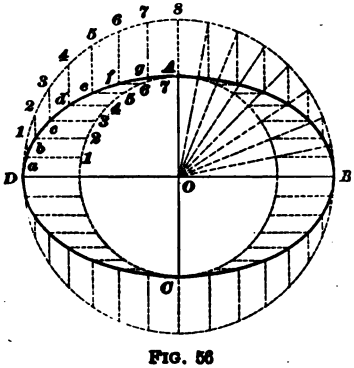


FIG. 56

lines; the points of intersection of these lines are points on the ellipse. Thus, the horizontal line $3c$ and the vertical line $3c$ intersecting at c give the point c of the ellipse. Trace a curve through the points thus found by placing an irregular curve on the drawing in such a manner that one of its bounding lines will pass through three or more points, judging with the eye whether the curve so traced bulges out too much or is too flat. Then adjust the curve again, so that its bounding line will pass through several more points, and so on, until the curve is completed. Care should be taken to make all changes in curvature as gradual as possible, and all curves drawn in this manner should be drawn in pencil before being inked in. It requires considerable practice to be able to draw a good curved line in this manner by means of an irregular curve, and the general appearance of a curve thus drawn depends a great deal upon the student's taste and the accuracy of his eye.

PROBLEM 24.—**To draw an ellipse by circular arcs.**

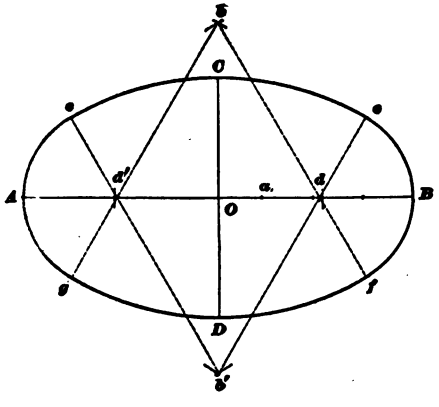


FIG. 57

This is not a true ellipse, but is very convenient for many purposes.

CONSTRUCTION. — In Fig. 57, use the same dimensions as before. On the major axis $A\,B$, set off $A\,a = C\,D$, the minor axis, and divide $a\,B$ into three equal parts. With O as a center, and a radius equal to the length of two of these parts, describe arcs cutting $A\,B$ in d and d'. Upon $d\,d'$ as a side, construct two equilateral triangles $d\,b\,d'$ and $d\,b'\,d'$. With b as a center, and a radius equal to $b\,D$, describe the arc $g\,D\,f$ intersecting $b\,d\,f$ and $b\,d'\,g$ in f and g. With the same radius, and b' as a center, describe the arc $c\,C\,e$

intersecting $b'd'c$ and $b'de$ in c and e. With A and B as centers, and a radius equal to the chord of the arcs Ac or Be, describe arcs cutting AB very near to d' and d. From the points of intersection of these arcs with AB as centers, and the same radius, describe the arcs cAg and eBf.

PROBLEM 25.—**To draw a parabola, the axis and longest double ordinate being given.**

EXPLANATION.—The curve shown in Fig. 58 is called a **parabola.** This curve and the ellipse are the bounding

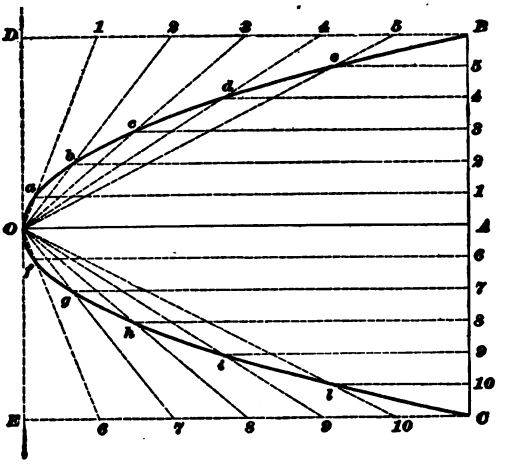


FIG. 58

lines of certain sections of a cone. The line OA, which bisects the area included between the curve and the line BC, is called the **axis.** Any line, BA or AC, drawn perpendicular to OA, and whose length is included between OA and the curve, is called an **ordinate.** Any line, as BC, both of whose extremities rest on the curve, and is perpendicular to the axis, is called a **double ordinate.** The point O is called the **vertex.**

CONSTRUCTION.—Make the axis OA equal to $3\frac{1}{2}''$, and the longest double ordinate BC equal to $3''$. BA, of course, equals AC. Draw DE through the other extremity of the

axis and perpendicular to it; also draw $B\,D$ and $C\,E$ parallel to $O\,A$ and intersecting $D\,E$ in D and E. Divide $D\,B$ and $A\,B$ into the same number of equal parts, as shown (in this case six); through the vertex O, draw $O\,1$, $O\,2$, etc. to the points of division on $D\,B$, and through the corresponding points *1*, *2*, etc., on $A\,B$, draw lines parallel to the axis. The points of intersection of these lines, *a*, *b*, *c*, etc., are points on the curve, through which it may be traced. In a similar manner, draw the lower half $O\,f\,g\,h\,i\,l\,C$ of the curve.

PROBLEM 26.—**To draw a helix, the pitch and the diameter being given.**

EXPLANATION.—The helix is a curve formed by a point moving around the cylinder and at the same time advancing along its length a certain distance; this forms the winding curved line shown in Fig. 59. The center line $A\,O$, drawn through the cylinder, is called the **axis** of the helix, and any line perpendicular to the axis and terminated by the helix is of the same length, being equal to the radius of the cylinder. The distance $B\,12$ that the point advances lengthwise during one revolution is called the **pitch.**

CONSTRUCTION.—As mentioned before, this figure occupies two spaces of the plate. The diameter of the cylinder is $3\frac{1}{2}''$, the pitch is $2''$, and a turn and a half of the helix is to be shown. The rectangle $F\,B\,E\,D$ is a side view of the cylinder, and the circle *1'*, *2'*, *3'*, *4'*, etc. is a bottom view. It will be noticed that one-half of a turn of the helix is shown dotted; this is because that part of it is on the other side of the cylinder, and cannot be seen. Lines that are hidden are drawn dotted. Draw the axis $O\,A$ in the center of the space. Draw $F\,D$ $3\frac{1}{2}''$ long and $4''$ from the top border line; on it construct a rectangle whose height $F\,B = 3''$. Take the center O of the circle $2\frac{3}{4}''$ below the point H on the axis $A\,O$, and describe a circle having a diameter of $3\frac{1}{2}''$, equal to the diameter of the cylinder. Lay off the pitch from B to *12* equal to $2''$, and divide it into a convenient number of equal parts (in this case 12), and divide the circle into the same

number of equal parts, beginning at one extremity of the diameter *12' O 6'*, drawn parallel to *B E*. At the point *1'* on the circle divisions, erect *1'–1'* perpendicular to *B E*; through the point *1* of the pitch divisions, draw *1–1'* parallel to *B E*, intersecting the perpendicular in *1'*, which is a point on the helix. Through the point *2'*, erect a perpendicular *2'–2'*, intersecting *2–2'* in *2'*, which is another point on the helix

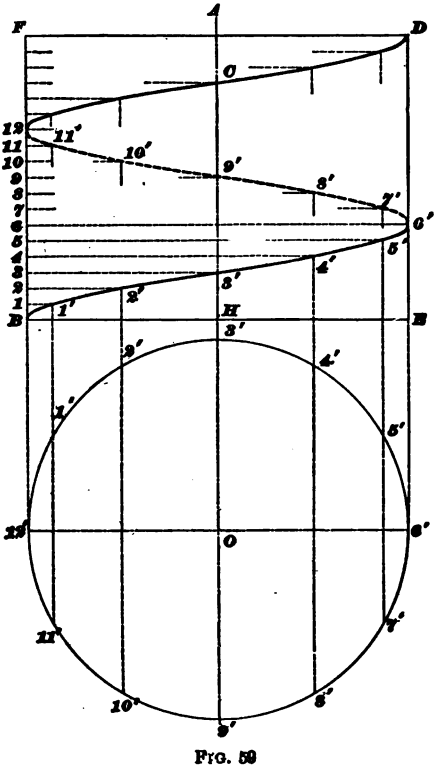


FIG. 59

So proceed until the point *6* is reached; from here on, until the point *12* of the helix is reached, the curve will be dotted. It will be noticed that the points of division *7'*, *8'*, *9'*, *10'*, and *11'* on the circle are directly opposite the points *5'*, *4'*, *3'*, *2'*, and *1'*; hence, it was not necessary to draw the lower half of the circle, since the point *5'* could have been the

starting point, and the operation could have been conducted backwards to find the points on the dotted upper half of the helix. The other full-curved line of the helix can be drawn in exactly the same manner as the first half.

This ends the subject of practical geometry. Mechanical drawing, or the representation of objects on plane surfaces, will now be commenced.

THE REPRESENTATION OF OBJECTS

40. There are five kinds of lines used in mechanical drawing, thus:

The light full line. ————————————————

The dotted line. –

The broken-and-dotted line. ——·——·——·——·——·——·——·——

The broken line. —— —— —— —— —— —— ——

The heavy full line. ————————————————

The light full line is used the most; it is used for drawing the outlines of figures, and all other parts that can be seen by the eye.

The dotted line, consisting of a series of very short dashes, is used in showing the position and shape of that part of the object represented by the drawing which is concealed from the eye in the view shown; for example, a hollow prism closed on all sides. The hollow part cannot be seen; hence its size, shape, and position are represented by dotted lines.

The broken-and-dotted line, consisting of a long dash, and two dots or very short dashes repeated regularly, is used to indicate the center lines of the figure or parts of the figure, and also to indicate where a section has been taken when a sectional view is shown. This line is sometimes used for construction lines in geometrical figures.

The broken line, consisting of a series of long dashes, is used in putting in the dimensions, and serves to prevent the dimension lines from being mistaken for lines of the drawing.

The heavy full lines are made not less than twice as thick as the light full lines, and are used for shade lines.

Further explanations in regard to these lines will be given when the necessity for using them arises.

41. The illustrations in this and the following paragraphs should be carefully studied, but the student is not required to send in drawings from same. In Fig. 60 is shown a perspective view of a frustum of a pyramid having a rectangular base and a hole passing through the center of the frustum. This figure represents the frustum as it actually appears when the eye of the observer is in a certain position. The angles at A, B, C, and D are right angles, the hole is round, and the sides $A\,B$ and $D\,C$ are of equal lengths; so also are $A\,D$ and $B\,C$; but, if they were measured on the drawing, it would be found that their lengths are all different. The same difficulty would be met with in trying to measure the angles and edges of the sides $A\,B\,F\,E$, $B\,F\,G\,C$, etc. The real length of any line can be found only by a person perfectly familiar with perspective drawing, and then only with great difficulty. Consequently, this method of representing objects is of no use to a patternmaker, carpenter, machinist, or engineer, except to show what the object looks like. In order to represent the object in such a manner that any line or angle can be measured directly, what is termed **projection drawing,** or *orthographic projection*, is universally employed. In the perspective drawing shown in Fig. 60, three sides of the frustum are shown, and the other three are hidden; in a projection drawing, but one side is usually shown, the other five being hidden.

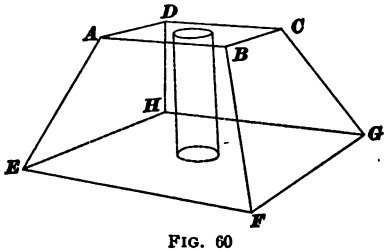


FIG. 60

A line or surface is *projected* upon a plane, by drawing perpendicular lines from points on the line or surface to the plane, and joining them.

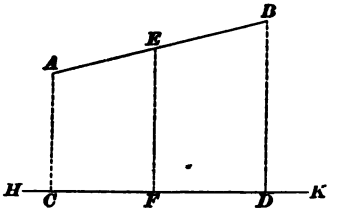


FIG. 61

Thus, if perpendiculars be drawn from the extremities of a line, as AB, to another line HK, as shown in Fig. 61, that portion of HK included between the feet of these perpendiculars is called the **projection** of AB upon HK. Thus, CD is the projection of AB upon HK, the point C is the projection of the point A upon HK, and the point D is the projection of the point B upon HK.

The projection of any point of AB, as E, can be found by drawing a perpendicular from E to HK, and the point where this perpendicular intersects HK is its projection. In this case, the point F is the projection of the point E upon HK.

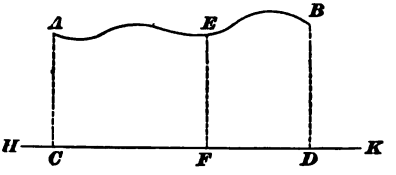


FIG. 62

It makes no difference whether the line is straight or curved—the method of finding the projection is exactly the same. See Fig. 62.

In a similar way, a surface is projected upon a flat surface.

Thus, it is desired to project the irregular surface $a\,b\,d\,c$, Fig. 63, upon the flat surface $A\,B\,D\,C$. Draw the lines $a\,a'$, $b\,b'$ perpendicular to the flat surface; join the points a' and b', where these perpendiculars intersect the flat surface $A\,B\,D\,C$, by a straight line $a'\,b'$, and $a'\,b'$ is the projection of the line $a\,b$ upon $A\,B\,D\,C$.

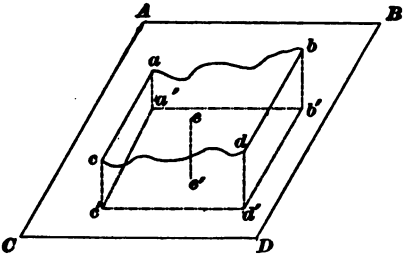


FIG. 63

In the same way, $a'\,c'$ is found to be the projection of $a\,c$; $c'\,d'$, the projection of $c\,d$; and $d'\,b'$, the projection of $d\,b$. Hence, the projection of the irregular

surface $a\,b\,d\,c$ upon the flat surface $A\,B\,D\,C$ is the quadrilateral $a'b'd'c'$.

The projection of any point, as e, is found as before, by drawing a perpendicular from the point e to the surface; thus, e' is the projection of the point e upon the plane $A\,B\,D\,C$.

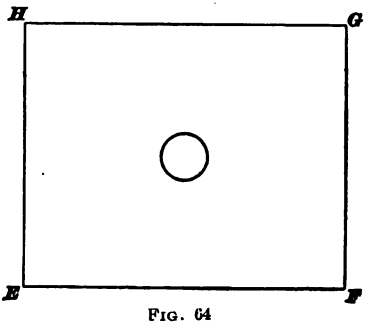


FIG. 64

Suppose that the frustum, Fig. 60, were placed on a plane surface (a surface perfectly flat, like a surface plate), and the outline of the bottom were traced by passing a pencil along its edges, including the round hole, the result would look like Fig. 64, in which the rectangle $E\,F\,G\,H$ represents the bottom of the frustum and the circle represents the hole.

The angles and lengths of the sides are exactly the same as they are on the frustum itself; a similar drawing could be made to represent the top, but it is unnecessary, for the reason that the top can be projected on Fig. 64, and both objects accomplished in one drawing. Fig. 65 illustrates the meaning of the last statement. Here $A'B'$ is the projection of the edge $A\,B$, Fig. 60; $B'C'$, of $B\,C$, etc.

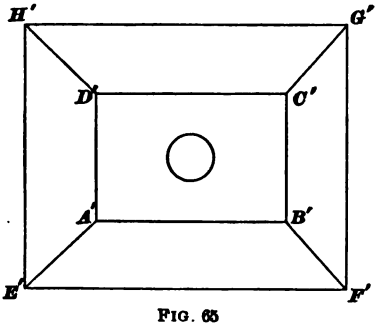


FIG. 65

$A'E'$ is the projection of the edge $A\,E$; $B'F'$, of $B\,F$, etc. This drawing shows the figure as it would look if the eye were directly over it. A drawing which represents the object as if it were resting on a horizontal plane, and the observer looking at it from above, is called a **top view**, or **plan**. The line of vision is thus perpendicular to the faces $A\,B\,C\,D$ and $E\,F\,G\,H$ of the frustum. The lines $A\,B$,

BC, etc., EF, FG, etc., and the diameter of the hole, can be measured directly. The drawing is not yet complete, since it does not show whether the ends and sides are rounding, hollowed out, or flat. For this purpose, two more views are necessary—*a vertical projection*, or *front view*, commonly called a **front elevation**, and a *side projection*, or **side view.** A front view (elevation) is drawn by imagining the eye to be so situated that the observer looks directly at the front of the object; in other words, the line of vision is parallel to the faces of the frustum. The side looked at is then drawn as if it were projected on a vertical plane at right angles to the horizontal plane, the vertical plane being also parallel to the edges EF and HG of the frustum shown in Fig. 60. The drawing would then look like Fig. 66. Here the trapezoid $ABFE$ represents the side $ABFE$ of the frustum; the altitude of the trapezoid being the same as the altitude of the frustum, it can be measured directly. The hole cannot be seen when the observer looks at the frustum in this position; hence, it is indicated by dotted lines. The projections of the lines AB and DC (also, of EF and HG, of AE and DH, and of BF and CG) coincide.

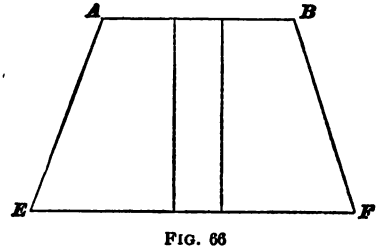


FIG. 66

To draw the side view (sometimes called a **side elevation**), imagine the frustum to be revolved around on its axis 90° to the left, and then draw it in precisely the same manner as the front elevation, by projecting the different lines upon a plane at right angles to the horizontal plane, and perpendicular to the edges EF and HG, that is, parallel to BC and FG. The side elevation would then be drawn as shown in Fig. 67. In this view the lines AD

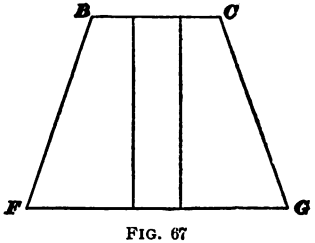


FIG. 67

and BC (also, EH and FG, DH and CG, and AE and BF) coincide.

42. In order to show clearly the different views, and to guard against one view being mistaken for another, they are always arranged on the drawing in a certain fixed and invariable manner. Fig. 68 shows this method of arrangement

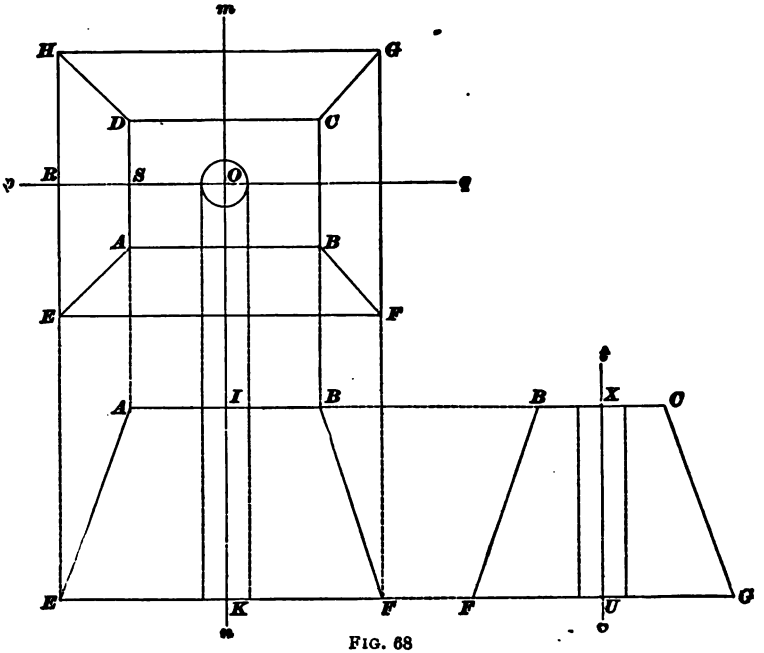


FIG. 68

The plan is drawn first, then the two elevations. It is usually immaterial which of these views is drawn first, but the general arrangement is as shown. Any departure from this method of arrangement should be distinctly specified on the drawing in writing, unless the purpose of the draftsman is so clearly evident that no explanation is needed. The broken and dotted lines are the **center lines**; they serve to show the connection existing between the different views of the object, and to indicate axes of cylindrical surfaces of any

kind. It will be noticed that, in the plan view, the two center lines cross each other at right angles, and that their point of intersection O is the center of the circle which represents the hole. Whenever a circle is drawn, two center lines should also be drawn through its center at right angles to each other; this enables any one looking at a drawing to instantly locate the center of any circle. This remark also applies to ellipses, semicircles etc.

To draw the frustum as shown in the last figure, either the front elevation or the plan is drawn first—whichever happens to be more convenient. Suppose the front elevation to be drawn first. Draw the vertical center line $m\ n$; measure the altitude of the frustum, and lay it off on this line, locating the points I and K; through these points, draw the lines $A\ B$ and $E\ F$ perpendicular to $m\ n$; make $A\ I = I\ B = \frac{1}{2}\ A\ B$, measured on the frustum; also $E\ K = K\ F = \frac{1}{2}\ E\ F$, measured on the frustum, and draw $A\ E$ and $B\ F$. Lay off the radius of the circular hole on both sides of the center line $m\ n$, and draw the dotted lines parallel to $m\ n$ through the extremities of these radii to represent the hole. The front elevation is now complete. To draw the plan, decide where the center is to be located on $m\ n$, and draw the horizontal center line $p\ q$. With the point of intersection O of the two center lines as a center, and with a radius equal to the radius of the hole, describe a circle. Through the points A, B, E, and F, draw indefinite straight lines parallel to $m\ n$. On both sides of the center line $p\ q$, lay off on these lines $D\ S$ and $S\ A$, equal to $\frac{1}{2}\ D\ A$, and $H\ R$ and $R\ E$, equal to $\frac{1}{2}\ H\ E$, both $D\ A$ and $H\ E$ being measured on the frustum. Through the points H, E, D, and A, draw the lines $H\ G$, $E\ F$, $D\ C$, and $A\ B$, and join the points H and D, E and A, F and B, and G and C by straight lines, as shown. The figure thus drawn will be the plan.

To draw the side elevation, prolong the lines $A\ B$ and $E\ F$, and draw the center line $t\ v$. Lay off, on each side of $t\ v$, $F\ U$ and $U\ G$ equal to $\frac{1}{2}\ F\ G$, measured on the frustum, and $B\ X$ and $X\ C$ equal to $\frac{1}{2}\ B\ C$, measured on the frustum. Join B and F, and C and G, by the straight lines

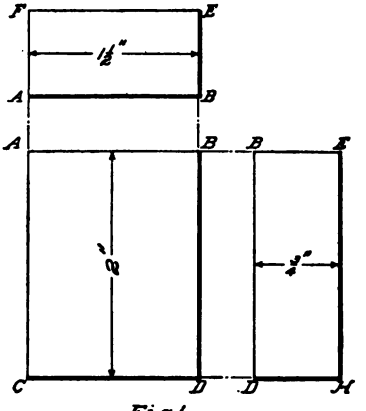


Fig.1.

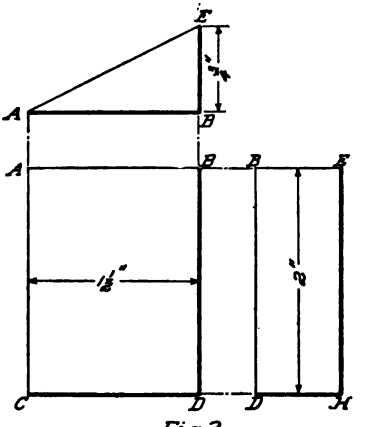


Fig.2.

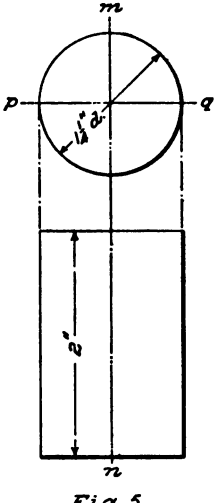


Fig. 5

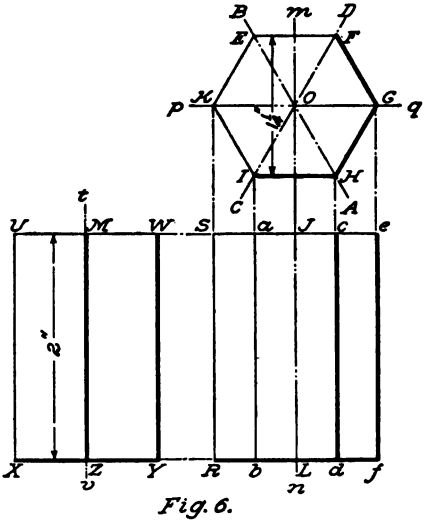
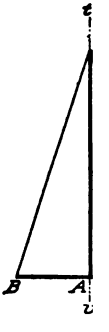


Fig. 6.



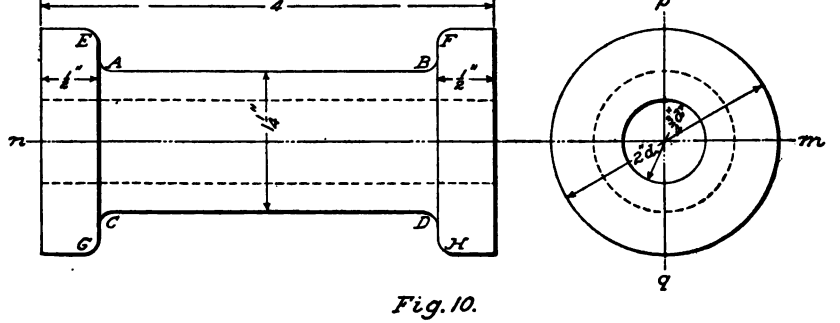


Fig. 10.

JECTIONS—I.

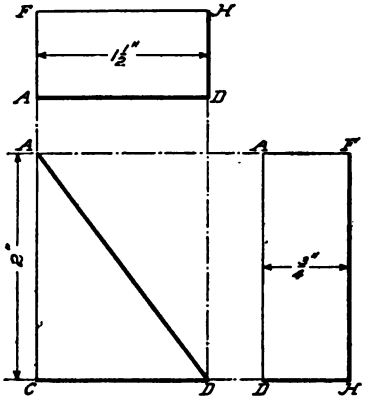


Fig. 3.

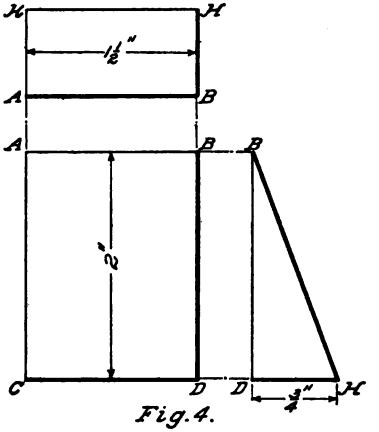


Fig. 4.

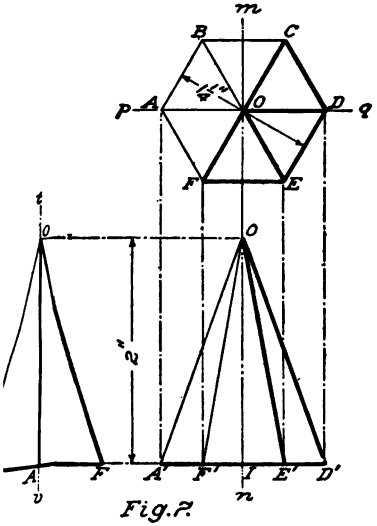


Fig. 7.

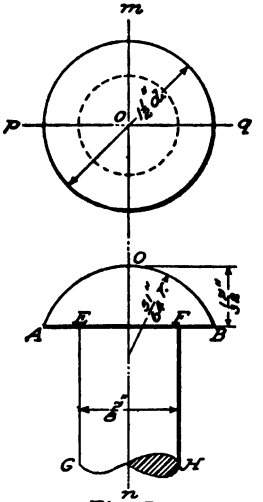


Fig. 8.

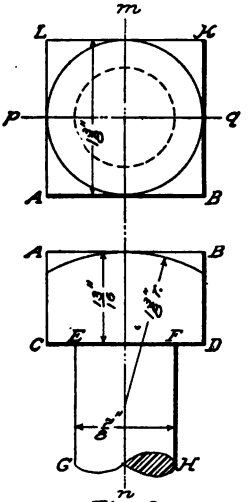


Fig. 9.

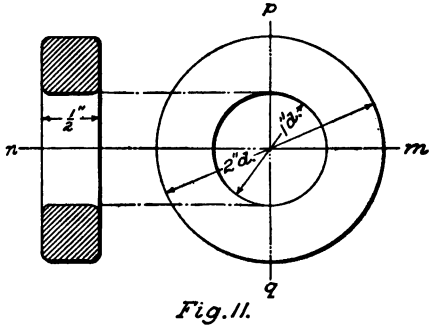


Fig. 11.

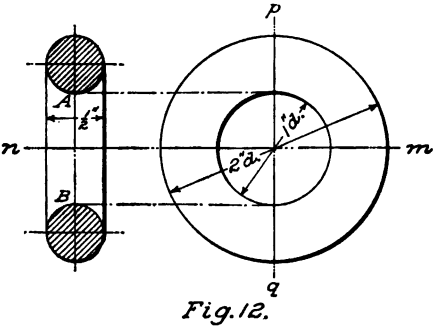


Fig. 12.

page immediately following the title page.

JOHN SMITH, CLASS N° 4529.

BF and CG, and draw the hole dotted as in the front elevation. The drawing is now complete.

The student should have by this time a good idea of how simple objects may be represented by the different views of a drawing, and can now begin on the next plate.

DRAWING PLATE, TITLE: PROJECTIONS—I

43. In making actual drawings of objects when the size of the plate is limited, it is usually impossible to divide it up into a certain number of parts, as in the case of the preceding plates, for the various figures differ widely in their sizes. These drawings should be so made that no part shall come nearer than $\frac{3}{4}''$ to the border line, and the figures should be so arranged as to present a pleasing appearance to the eye, and not be scattered aimlessly all over the drawing.

Fig. 1 represents a **rectangular prism** $2''$ long, $1\frac{1}{2}''$ wide, and $\frac{3}{4}''$ thick. The prism is represented as if it were standing on one of its small ends, with the broad side towards the observer. The elevation $ABDC$ is drawn first; in this case, it will be a rectangle $2'' \times 1\frac{1}{2}''$. The top view, or plan, $FEBA$ is next drawn; this is a rectangle $1\frac{1}{2}'' \times \frac{3}{4}''$, the side AB being the projection of the front of the prism, and the side FE of its back. Lastly, the side elevation is drawn; this is another rectangle $BEHD$, $2'' \times \frac{3}{4}''$, the side BD representing the projection of the front of the prism, and the side BE corresponding to the right-hand end BE of the plan.

Fig. 2 is a **wedge** standing on one of its triangular ends. It is the rectangle shown in Fig. 1, cut diagonally through the corner from E to A on the plan. It will be noticed that the two elevations are exactly the same as in Fig. 1, the plan showing the difference between the two figures.

Fig. 3 is another wedge, standing on one of its rectangular sides, formed by cutting through the prism, in Fig. 1, from A to D. The plan and side elevation are the same as in Fig. 1. Here, the front elevation shows the difference

between Figs. 1 and 3. The point D of the elevation is projected on the plan in the point D, and the point opposite D, perpendicular to the plane of the paper, is the point H, shown in all of the side elevations.

Fig. 4 is also a wedge; it is formed by cutting through the prism in Fig. 1 from B to H. The front elevation and plan are the same as shown in Fig. 1, the side elevation being different. The point H in the side elevation opposite D is here projected in the point H of the plan; the point opposite C in the front elevation, and opposite H in the side elevation, is projected in the point K of the plan, the line $K H$ being opposite $C D$ in the plane of the base.

Fig. 5 shows a **cylinder** $1\frac{1}{4}''$ in diameter and $2''$ long. The side elevation is not given, since all elevations of a cylinder whose bases are perpendicular to its axis are the same. Either view may be drawn first, according to convenience.

Fig. 6 shows a **hexagonal prism** $2''$ long; the distance between any two parallel sides is $1\frac{1}{4}''$. In this case, the plan (a regular hexagon) must be drawn first. It is desired also that two of the parallel sides shall be horizontal. To draw the plan in this position, with the dimensions given, choose the center O of the hexagon; draw two center lines at right angles to each other, as $m n$ and $p q$. With O as a center, and a radius equal to one-half of the distance between two parallel sides ($1\frac{1}{4}'' \times \frac{1}{2} = \frac{5}{8}''$), describe a circle. Now, use the T square to draw two horizontal lines through the points of intersection of this circle with the center line $m n$. By means of the T square and 60° triangle, draw $A B$ and $C D$ through O, in such a manner that the angles $A O q$ and $C O p$ each equal 60°; this is done by keeping the longer of the two short sides of the triangle vertical, and passing the pencil along the hypotenuse. Through E and H, the points of intersection of $A B$ with the two parallel lines, draw $E K$ and $H G$ parallel to $C D$; and through F and I, the points of intersection of $C D$ with the two parallels, draw $F G$ and $K I$ parallel to $A B$. This completes the hexagon, and also the plan of the prism. To draw the front elevation, measure

off, on the center line $m\,n$, the distance $J\,L$ equal to 2″, and through the points J and L draw the two horizontal lines $S\,e$ and $R\,f$. Project the points K, I, H, and G upon $S\,e$, as shown by the dotted lines; and through the points of intersection of these dotted lines with $S\,e$, draw the vertical lines $S\,R$, $a\,b$, $c\,d$, and $e\,f$, thus completing the front elevation. To draw the side elevation, extend the lines $S\,e$ and $R\,f$, and draw the center line $t\,v$. Make $U\,W$ equal to $1\frac{1}{4}$″, which is equal to the distance between the parallel sides, and draw $U\,X$ and $W\,Y$; also, $M\,Z$, the point M corresponding to the point K of the plan.

Fig. 7 represents a **hexagonal pyramid**; the distance between two parallel sides of the base is $1\frac{1}{4}$″, and the altitude is 2″. As in Fig. 6, the plan must be drawn first. Then, to draw the front elevation, lay off $O\,I$ on the center line $m\,n$ equal to the altitude, and through I draw the base line $A'D'$. Project the points D, E, etc. of the plan upon $A'D'$, as shown by the dotted lines, and join them with the point O by the straight lines $A'O$, $F'O$, $E'O$, and $D'O$; these lines are the vertical projections of the edges of the pyramid; the horizontal projections of the edges are $F\,O$, $E\,O$, $D\,O$, etc. The side elevation can be easily drawn, and does not require a special description, the length of the base $B\,F$ being equal to the distance between the parallel sides, or $1\frac{1}{4}$″.

Fig. 8 shows a **rivet** $\frac{7}{8}$″ in diameter, having a button head $1\frac{1}{2}$″ in diameter. The side elevation is not given, since it is exactly the same as the front elevation. Either of the two views may be drawn first, according to convenience. Suppose that the elevation is first drawn. Draw the center line $m\,n$, and the line $A\,B$ for the base of the head. On the center line lay off from the line $A\,B$, or the base of the head, a point O, at a distance of $\frac{7}{32}$″, the height of the head. With the compasses set to a radius of $\frac{5}{64}$″, and from a point on the center line $m\,n$, describe an arc $A\,O\,B$, taking care to pass this arc through the point O. Lay off from, and on both sides of, the center line $m\,n$ a distance of $\frac{7}{16}$″, or $\frac{1}{2}$ of the diameter of the rivet, and draw $E\,G$ and $F\,H$. Draw the other center line $p\,q$ of the plan, and with O as a center,

and a radius equal to the radius of the button head, describe a circle. With the same center, and a radius equal to $\frac{7}{16}''$, describe the dotted circle, the horizontal projection of the rivet. The irregular line $G H$ indicates that only a part of the rivet is shown. This is done so as not to take up too much space on the drawing.

Fig. 9 shows an ordinary **square-headed bolt** $\frac{7}{8}''$ in diameter, having a head $1\frac{3}{8}''$ square and $\frac{13}{16}''$ thick. Draw the center lines $m n$ and $p q$. Construct the rectangle $A B D C$, $1\frac{3}{8}'' \times \frac{13}{16}''$, the elevation of the head. Locate the points E and F at a distance of $\frac{7}{16}''$ from each side of the center line, and draw $E G$ and $F H$. With the compasses set to a radius of $1\frac{3}{8}''$ and from a point on the center line $m n$, describe the arc representing the chamfering of the head. Draw the plan of the head $L K B A$ (a square whose edge measures $1\frac{3}{8}''$), and the dotted circle $\frac{7}{8}''$ in diameter, the projection of the body of the bolt, which cannot be seen in this view.

Fig. 10 shows a **distance piece** used to separate two other parts, and to keep them a certain distance apart. The arrangement of the views of this figure is somewhat different from the preceding ones, in order to make room for it on the drawing. Draw the center line $n m$, and construct the figure according to the dimensions marked on the plate. Use a radius of $\frac{1}{8}''$ for the fillets at A, B, C, and D, and an equal radius to round the corners at E, F, G, and H.

Fig. 11 shows a **square cast-iron washer.** Instead of making an elevation and plan as usual, a section is taken through $p q$; that is, the washer is imagined to be cut on the line $p q$, with all that part of the figure to the left of $p q$ removed, and an elevation drawn of the remaining part. In order to distinguish a sectional drawing without any possibility of mistake, the so-called section lines are employed. These are usually drawn by laying a 45° triangle against the edge of the T square, and drawing a series of parallel lines as nearly equally distant apart as can be judged by the eye. For cast iron, these lines are full, thin lines, all of the same

thickness, and must not be drawn too near together. The method of sectioning for other materials will be given later on. It is not usual to draw the section lines in pencil, but to wait until the outlines of the drawing have been inked in, and then section directly with the drawing pen. The shortest distance apart of the section lines should rarely be *less* than $\frac{1}{16}''$, unless the drawing is of such small dimensions as to cause a sectioning of this width to look coarse. This is the case with Figs. 11 and 12 of this plate. In these two figures make the section lines a full $\frac{1}{32}''$ apart. Only that part of the figure is sectioned which is touched by the cutting plane, the rest of the figure being drawn as if it were projected upon the cutting plane. The corners of this figure should be rounded with a radius of $\frac{1}{16}''$; the other dimensions can be obtained from the plate.

Fig. 12 is a **cast-iron cylindrical ring.** It is shown in plan and section. The dimensions given suffice for the drawing of the figure without further explanations. The inner circle of plan is the projection of the innermost points of the ring which form a circle whose diameter is *A B*.

44. When inking in a drawing, it is generally best to draw the circles and other curved lines first, and the straight lines afterwards. This enables the draftsman to easily blend into one line the straight lines meeting the curves, so that their points of meeting cannot be detected; it enables the tangent lines to be drawn with better success, and also shortens the time of inking in a drawing. It will be noticed that some of the straight lines are heavy and some light, and that parts of the full-line circles are heavy and the rest of the circle light. These are the shade lines; they are described later on. The student may make all of the full lines except the border lines of this plate, and the three following plates, of the same thickness, if he so desires. The dotted lines used to indicate those parts of the figures that are hidden must be of the same thickness as full lines, while the construction lines and center lines should be very thin.

45. Dimensions.—The dimension lines and figures on this and succeeding plates are to be inked in by the student.

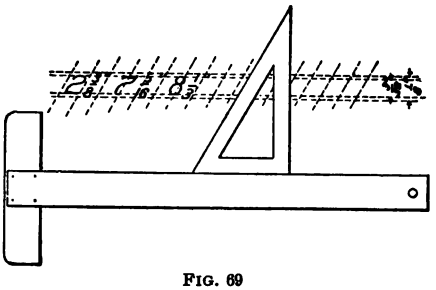


FIG. 69

Make the dimension figures $\frac{3}{32}''$ high, and of the same style as those shown in Art. **20.** Fractions should be $\frac{1}{8}''$ high over all. If there is not room for figures of this size, great care should be taken to make them *clear*.

Until after the student has obtained sufficient practice in lettering, he should draw guide lines in pencil for the dimension figures, as in Fig. 69, unless he can make them look well without. All the figures should have the same slant of 60°, and, when printing fractional dimensions, the *whole* fraction should have the same slant as the figures; that is, the denominator should be under the numerator in a *slanting* direction, and not straight below it. Make the dividing line between the numerator and denominator horizontal, not slanting.

Dimension and extension lines must be light, broken lines of the same thickness as the center and construction lines. Care should be exercised to make the arrowheads as neatly as possible and of a uniform size. They are made with a Gillott's No. 303 pen, and their points must touch the extension lines, as illustrated in Fig. 70. Do not make arrowheads too flaring.

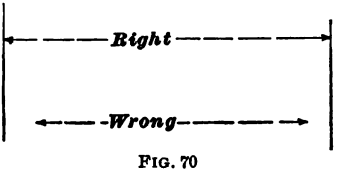


FIG. 70

When putting in the dimensions, care should be taken to give *all* that would be needed to make the piece which the drawing represents, but do not repeat the same dimension on different views. Thus, in Fig. 1 of this plate, the length is given in the front elevation as 2″, and it is obviously unnecessary to give the same dimension in the side elevation

PROJECTION

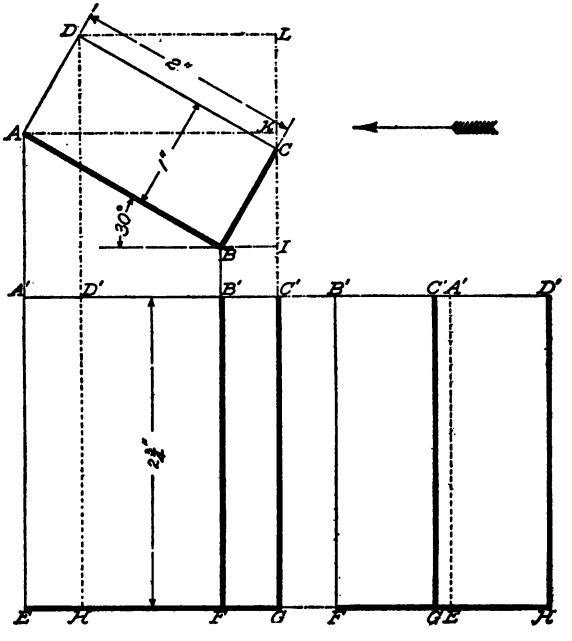


Fig. 1.

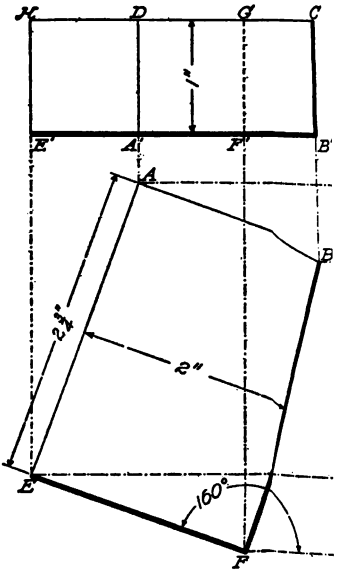


Fig. 2.

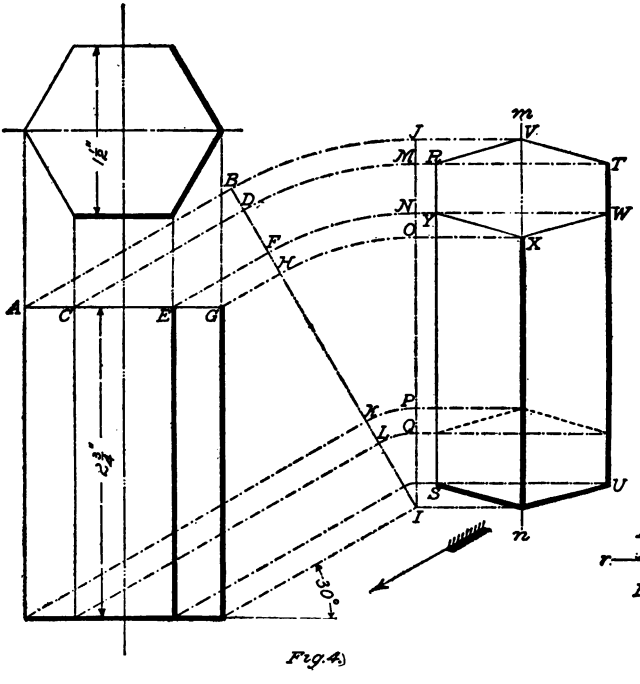


Fig. 4.

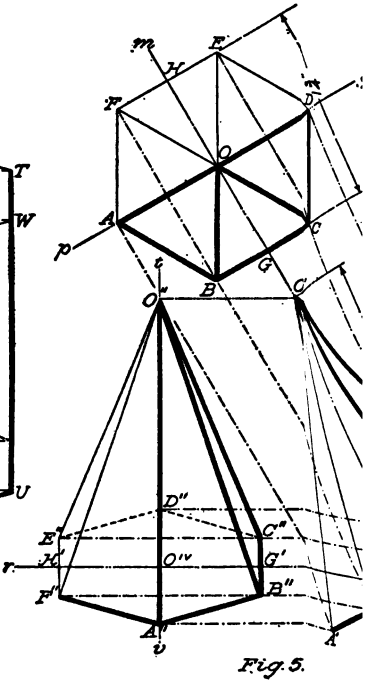
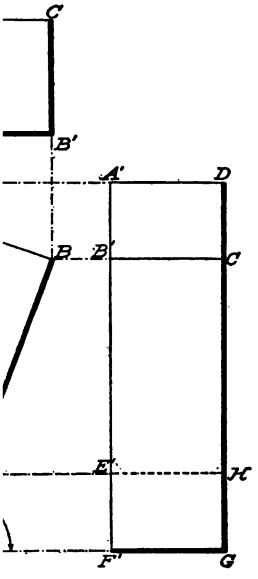


Fig. 5.

IONS-II.



y. 2.

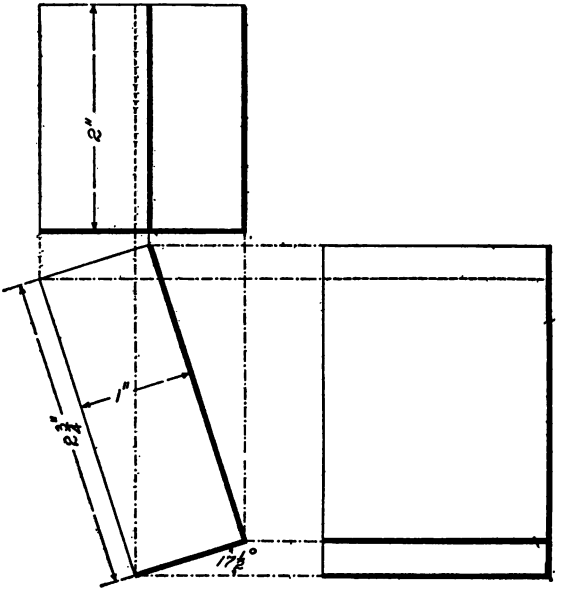
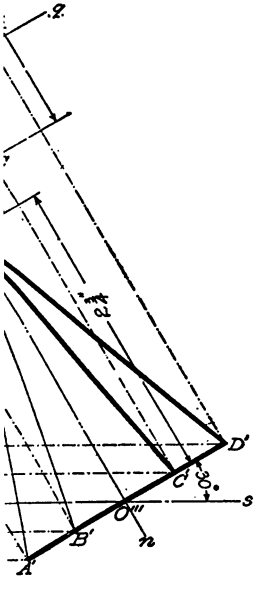


Fig. 3.



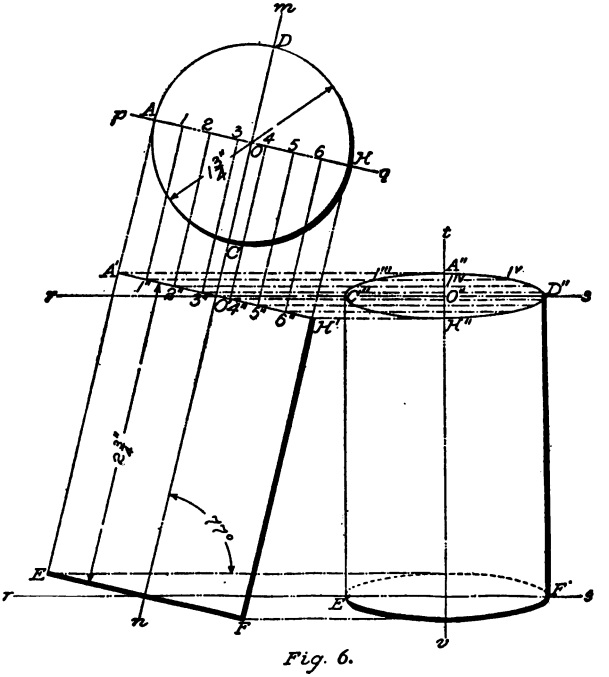


Fig. 6.

Again, the dimension lines should be put where they would be most likely to be looked for. In Fig. 10 of this plate, the diameter of the central part of the distance piece is marked $1\frac{1}{4}''$ in the elevation; it could have been marked on the side elevation, as the diameter of the dotted circle, but a person wishing to find the size of this part of the piece would naturally look for it in the front elevation. This is also true of the diameter of the flange. The diameter of the hole could be on the plan or elevation, but it is put on the plan because it is denoted there by a full line, while in the elevation the hole is dotted. Never cross one dimension line by another, if it can well be avoided. Thus, in Figs. 2 and 4 of this plate, the bounding lines of the triangular views are extended by fine broken lines, in order that the dimension lines ($\frac{3}{4}''$) may not cross the lines marking the length and width of the wedge.

The student should ink in all the figures used for dimensions shown on this and succeeding plates, on his drawing, but should omit the letters used to describe the different objects. The titles should be made in block letters as shown on sample copies. The date, name, course letter, and class number are to be put on as in the preceding plates.

DRAWING PLATE, TITLE: PROJECTIONS—II

46. The figures on the last plate were drawn under the supposition that the center lines, and at least one flat side, were parallel to the plane of the paper—the center lines were also either vertical or horizontal. This is always possible in detail drawings, where each piece is drawn separately by itself, but in the case of machines, where the parts are placed at different angles, they cannot always be drawn in this manner. The figures on this plate are so drawn that they show objects similar to those in the last plate, but at different angles. The student should exercise particular care to understand this plate and the

two succeeding ones; if he thoroughly masters them, he should experience no great difficulty in the plates that follow.

Fig. 1 shows a **rectangular prism** $2\frac{3}{4}''$ long, 2″ wide, and 1″ thick, standing in a perpendicular position on one of its small ends in such a manner that the broad sides make an angle of 30° with a horizontal line. Draw the plan first. To do this, construct the rectangle $A\,B\,C\,D$ 2″ × 1″, with the parallel edges $A\,B$ and $D\,C$ making an angle of 30° with the horizontal; this may be done by holding the head of the T square against the left-hand end of the board, and using the 60° triangle. To construct the front elevation, draw a horizontal line $A'C'$ and project A upon this line, thus obtaining the point A'. Draw $A'E$ perpendicular to $A'C'$, and make it equal in length to $2\frac{3}{4}''$, the length of the prism. Through E draw $E\,G$. Project the points B and C upon $A'C'$, and draw $B'F$ and $C'G$. The back edge $D'H$ of the prism is not seen, and, hence, its position is indicated by the dotted line $D'H$.

The side elevation can be drawn in a similar manner by projecting the points $A\,B\,C\,D$ upon a vertical line, as $I\,L$. Produce $A'C'$ and $E\,G$, and make $B'D'$ equal to $I\,L$. Now use the spacing dividers, and set off $B'C'$ equal to $I\,C$, and $B'A'$ equal to $I\,K$. Through B', C', A', and D', draw the vertical lines $B'F$, $C'G$, $A'E$, and $D'H$, drawing $A'E$ dotted, because, when looking at the prism in the direction of the arrow, the edge $A'E$ is not seen.

Fig 2 is the same **prism** shown in Fig. 1, but in a different position. The two broad sides are parallel to the plane of the paper, and the prism is tipped in such a manner that the base makes an angle of 160° with the horizontal. The elevation must be drawn first. To do this, draw a horizontal line; then, by using the protractor, draw the line $E\,F$, making an angle of 160° with the horizontal, reckoning from right around to the left, opposite to the motion of the hands of a clock. Make $E\,F$ equal in length to 2″, and on it construct the rectangle $E\,F\,B\,A$, $2\frac{3}{4}''$ × 2″; it will be the vertical

projection or front elevation of the prism. The method of drawing the plan and side elevation is apparent without further explanation.

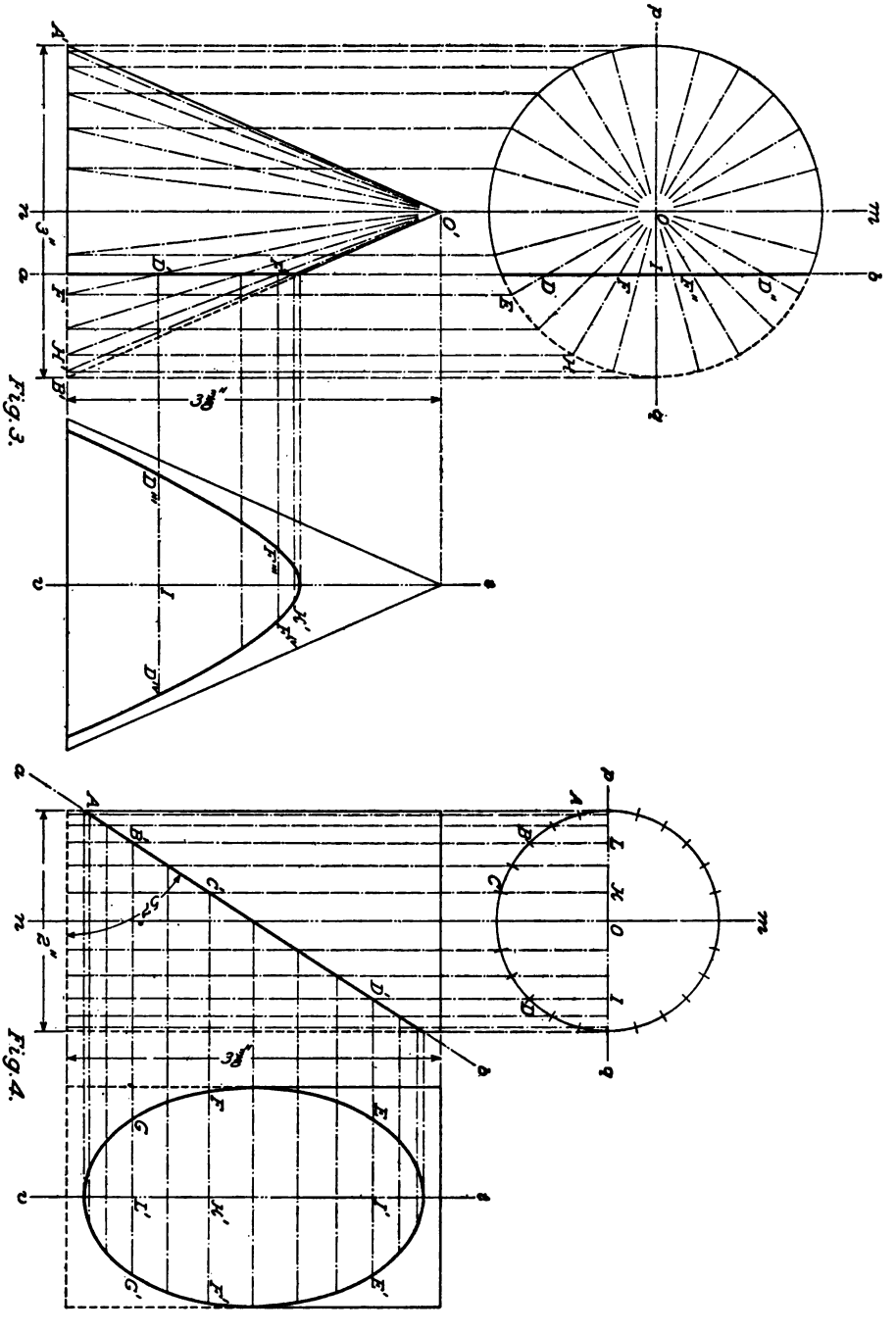
Fig. 3 is the same **prism** shown in Figs. 1 and 2, but with the narrow sides parallel to the plane of the paper, and tipped until the base makes an angle of $17\frac{1}{2}°$ with the horizontal. The sizes are the same as in the two preceding figures, and it should be drawn without further explanation, the front elevation being drawn first.

Fig. 4 shows a **hexagonal prism** having two of its parallel sides parallel to the plane of the paper, and its axis vertical; instead of a side elevation at right angles to the horizontal, a side elevation is desired, as if the vertical prism were looked at in the direction of the arrow, or at an angle of 30° with the horizontal. Draw the plan first and then the front elevation from the dimensions given. To draw the other view, first draw the center line *m n*, and then, by use of the T square and 30° triangle, draw the lines *A B*, *C D*, *E F*, and *G H*, from the points *A*, *C*, *E*, and *G*, as shown. Also draw in a similar manner the other four dotted lines at the base of the prism; then draw the line *I B* at a right angle to the lines *A B*, *C D*, etc. At the point *I*, draw the line *I J* parallel to the center line *m n*, and, with *I* as a center, and the points *B*, *D*, *F*, *H*, *K*, *L*, etc. as radii describe arcs, as shown, cutting the vertical line *I J* at the points *J*, *M*, *N*, *O*, *P*, *Q*, etc. Through the points *J*, *M*, *N*, *O*, *P*, *Q*, etc. draw horizontal lines as shown. On each side of the vertical center line *m n*, lay off a distance of $\frac{3}{4}''$, or one-half the distance between the parallel sides of the prism, which is $1\frac{1}{2}''$, as shown in the plan, and draw the lines *R S* and *T U*. This view is then completed by drawing the lines *V R*, *V T*, *W X*, and *Y X*, as shown. The lines at the base are drawn in a similar manner.

Fig. 5 represents a **hexagonal pyramid** whose axis is parallel to the plane of the paper, the base making an angle of 30° with the horizontal. It is desired to find the vertical projection of the side elevation. Having drawn the plan *A B C D E F* and the side elevation *O'A'B'C'D'*, as shown

from the dimensions marked on the drawing, choose the position of the vertical center line $t\,v$; project O' and O''' upon it in the points O'' and O^{IV}, and, through O^{IV} and O''', draw a fourth center line $r\,s$. On this, lay off $O^{IV}\,G'$ and $O^{IV}\,H'$ equal to $O\,G$ and $O\,H$, and construct the projection $A''\,B''\,C''\,D''\,E''\,F''$, as indicated by the broken and dotted lines. Join $O''\,E''$, $O''\,F''$, etc. by straight lines, and it will be the required projection. The figure thus drawn represents the pyramid as it would appear placed so that its base made an angle of 30° with the horizon, the line of vision being horizontal to the observer looking at it from the left side.

Fig. 6 shows a **cylinder** whose axis is parallel to the plane of the paper and makes an angle of 77° with the horizontal. The vertical side projection is required. Draw the plan and front projection as shown from the dimensions given. Draw the center line $t\,v$ vertical, and project the center O' upon it in O''; also, A' in A'', and H' in H''. To find the remaining points on the projected circle, divide the diameter $A\,H$ of the plan into a convenient number of equal parts, in this case 7, as $A\,1$, 1–2, 2–3, etc. Through the points thus laid off, draw the lines 1–$1''$, 2–$2''$, 3–$3''$, etc., parallel to the center line $m\,n$. Through the points A', $1''$, $2''$, $3''$, etc., draw the horizontal lines as shown by the dotted lines. From and on each side of the vertical center line $t\,v$, lay off distances on each side of the horizontal lines just drawn equal to the length of that part of the lines 1–$1''$, 2–$2''$, 3–$3''$, etc. included between the center line $p\,q$ and the semicircle $A\,C\,H$; thus, on the horizontal line drawn through the point O', the distances $O'\,C'$ and $O''\,D''$ are each equal to $O\,C$ in the plan. The distances 1^{IV}–$1'''$ and 1^{IV}–1^{V} are each equal to the distance from 1 to the point of intersection of the semicircle on the line 1–$1''$. The remaining distances are laid off in a similar manner. A curve traced through the points thus found will be the required projection of the upper base of the cylinder. The projection of the lower base is found in exactly the same way. Drawing $C''E'$ and $D''F'$ completes the required projection.



CONIC SECTIONS.

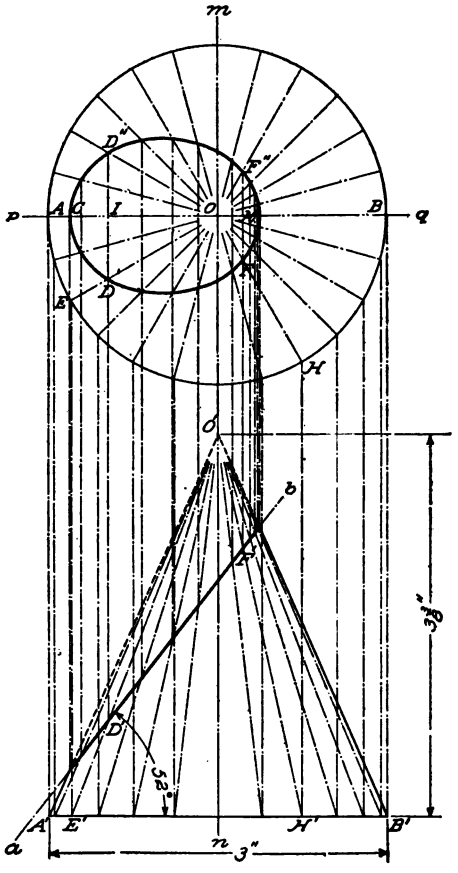


Fig. 1.

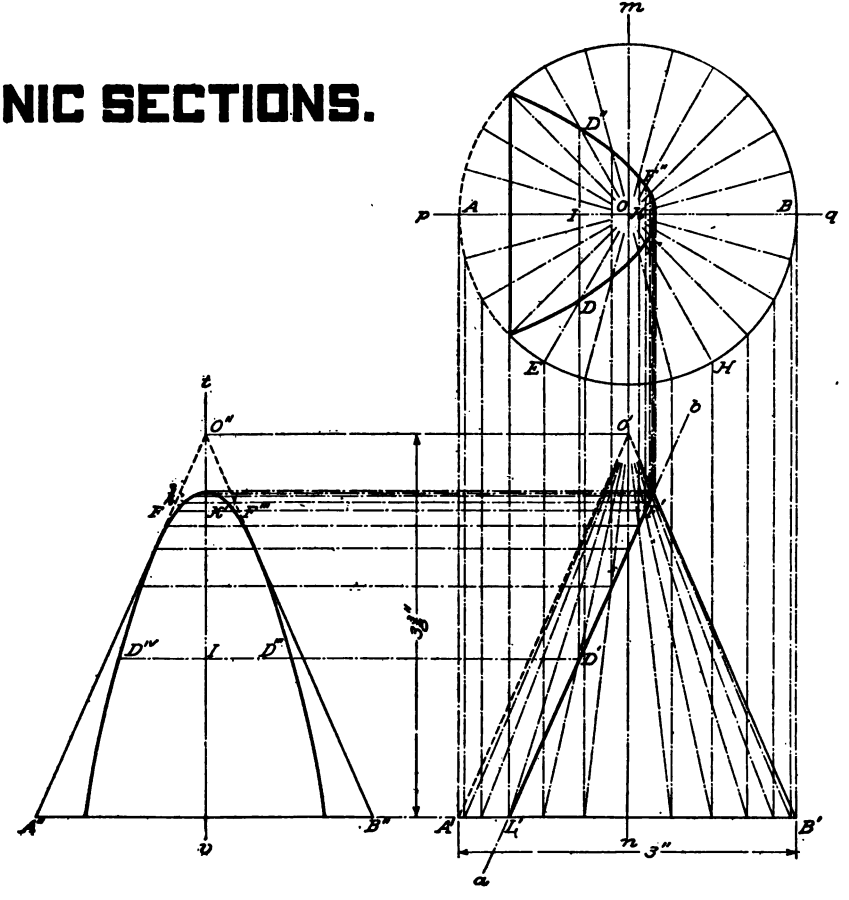


Fig. 2.

see page immediately following the title page.

DRAWING PLATE, TITLE: CONIC SECTIONS.

47. This plate shows the different forms of the curves formed by the intersection of a cone or cylinder by a plane. If the plane of intersection is perpendicular to the axis of the cone or cylinder, the curve of the intersection will be a circle; but if it is inclined to the axis, it will be an ellipse in the case of a cylinder, and an ellipse, hyperbola, or parabola in the case of a cone, according to the angle of inclination.

Fig. 1 is a **cone cut by a plane** which does not intersect the base of the cone. *When the cutting plane does not intersect the base*, or the new base of the cone when the cone is extended, the curve of intersection is an **ellipse.**

Draw the plan and front elevation of a right cone whose altitude is 3⅜ inches and whose base is 3 inches in diameter. Cut this cone by a plane *a b*, making an angle of 52° with the base. See figure.

Divide the circle which represents the base of the cone in the plan into any number of parts, in this case 24, and, through the points of division *A*, *E*, *H*, etc., draw the radii *O A*, *O E*, *O H*, etc. to the center *O*. Draw also from these points straight lines *A A'*, *E E'*, *H H'*, *B B'*, etc., parallel to the axis of the cone *O'n*, and cutting the base *A'B'* in the points *E'*, *H'*, etc. From these points, draw lines to the apex *O'* of the cone, and cutting the base *A' B'* in points *E'*, *H'*, etc. From these points, draw lines to the apex *O'* of the cone, as *E'O'*, *H'O'*, etc., cutting the plane *a b* in the points *D'*, *F'*, etc. From these points *D'*, *F'*, etc., draw straight lines *F'F F''*, *D'D D''*, etc., parallel to the axis *O'n* of the cone, and intersecting the radii *O A*, *O E*, *O H*, *O B*, etc., in the points *C*, *D*, *F*, *K*, *F''*, *D''*, etc., and through these points of intersection draw the ellipse by aid of an irregular curve.

Fig. 2 is a cone of the same size as in the preceding problem; but the cutting plane *a b* is, in this case, parallel to one of the elements* of the cone, and intersects the base. The

*Any straight line drawn on the surface of a cone and passing through the apex (as *O'H'*. Fig. 1. or *O'A'*. Fig. 2, etc.) is called an **element.**

curve formed by the intersection of a cone by a plane parallel to one of its elements is called a **parabola.** The plan and front elevations of the cone and curve of intersection are found in a manner similar to the method used in the last problem. To find the side elevation, proceed as follows: Draw the side elevation $O''A''B''$ of the cone with the center line $t\,v$ as its axis. Draw the projection lines $F'F'''F^{IV}$, $D'D'''D^{IV}$, etc., and make $K'F'''$ and $K'F^{IV}$ equal to KF and KF''; make $I'D'''$ and $I'D^{IV}$ equal to ID and ID'', etc., and trace a curve through the points thus found. The result will be the side elevation of the cone when cut by a plane parallel to one of its elements and having the upper part removed. The side elevation of Fig. 1 may be drawn in a similar manner.

Fig. 3 is a cone having the same dimensions as the two preceding problems, but cut by a plane $a\,b$ parallel to the axis of the cone and perpendicular to the vertical plane of projection. When the cutting plane intersects the base of a cone and is not parallel to any element (that is, if the acute angle included between the cutting plane and the base is greater than the angle $O'A'B'$ included between any one element and the base), the curve of intersection is called a **hyperbola.**

The plan and front elevation are constructed as before, the horizontal projection of the curve for this particular case, where the cutting plane is parallel to the axis of the cone, is also a straight line. The side elevation is found as in the last problem, by drawing the lines of projection $F'F'''F^{IV}$, $D'D'''D^{IV}$, etc., and making $I'D'''$ and $I'D^{IV}$ equal to ID and ID'', $K'F'''$ and $K'F^{IV}$, equal to IF and IF'', etc. The curve drawn through the points thus found will be the required hyperbola.

Fig. 4 shows the **intersection of a cylinder,** $3\frac{3}{8}''$ long and $2''$ in diameter, by a plane $a\,b$, making an angle of $57°$ with the base. The plan and elevation may be drawn as shown, the horizontal projection of the curve being a circle, having the same diameter as the base. To construct the side elevation of the curve, divide the circle representing the

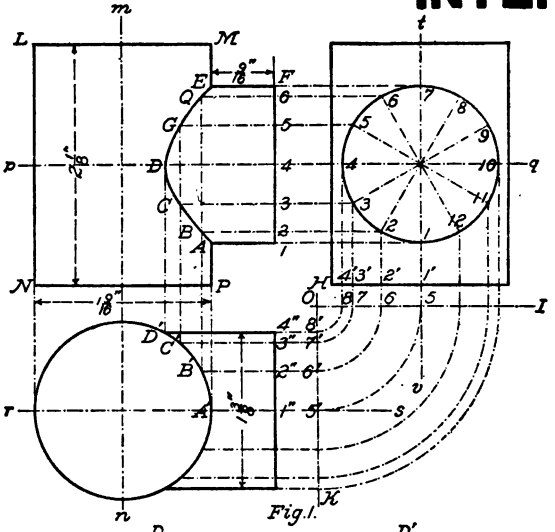


Fig.1.

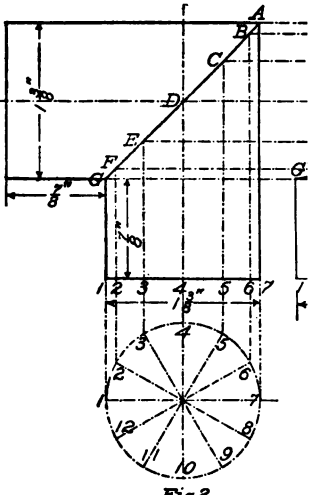


Fig.2.

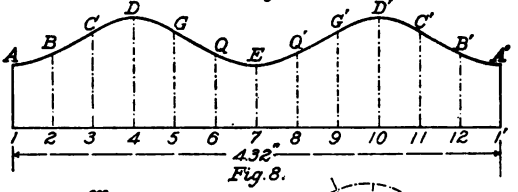


Fig.8.

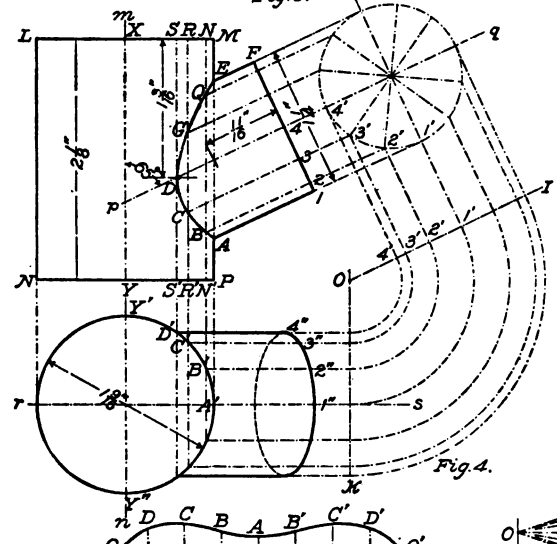


Fig.4.

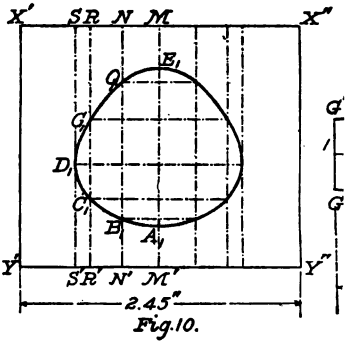


Fig.10.

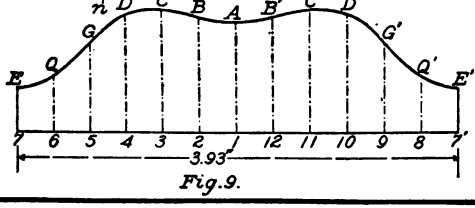


Fig.9.

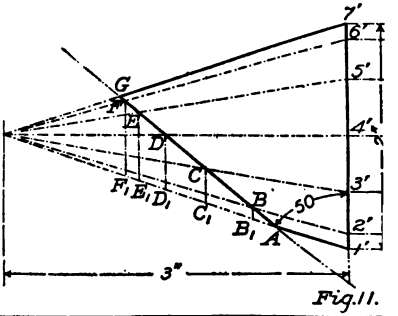


Fig.11.

...ND DEVELOPMENTS.

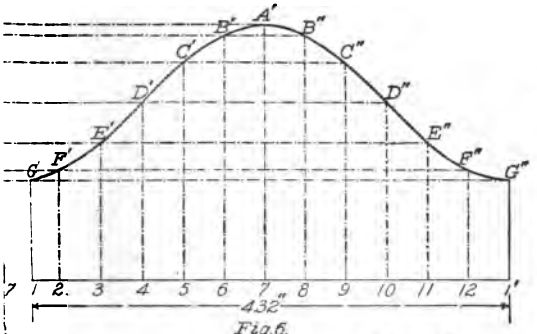


Fig.6.

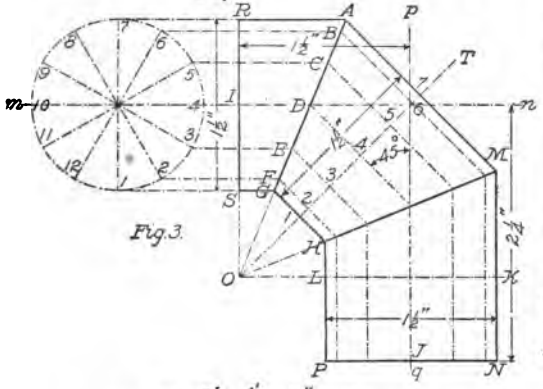


Fig.3.

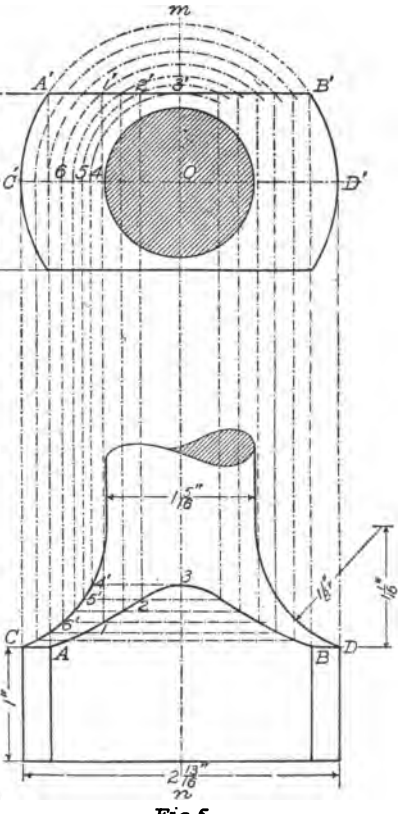


Fig.5.

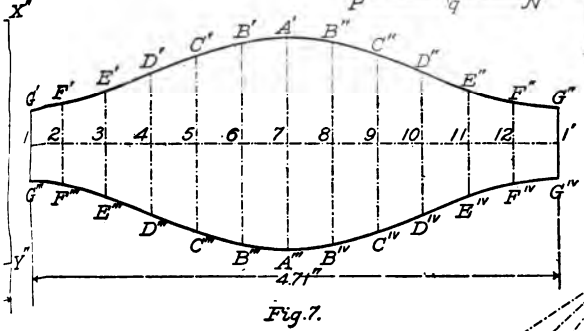


Fig.7.

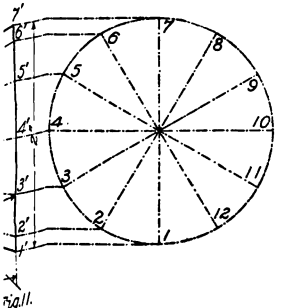


Fig.11.

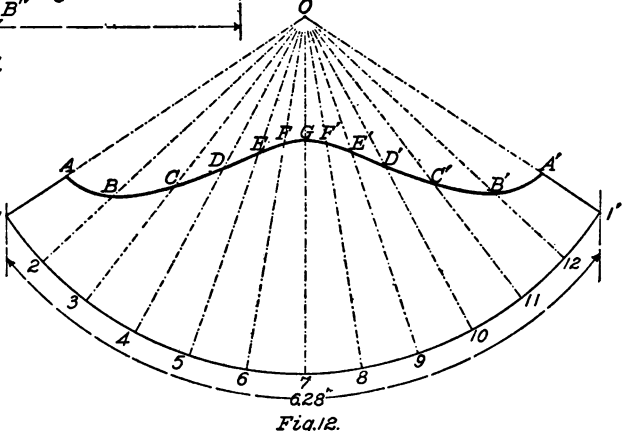


Fig.12.

base of the cylinder in the plan into any number of parts, in this case 24, and through the points of division A, B, C, etc. draw the radii $O\,A$, $O\,B$, $O\,C$, etc. to the center O. Draw also from these points straight lines $A\,A$, $L\,B\,B'$, $K\,C\,C'$, $I\,D\,D'$, etc. parallel to the axis $m\,n$ of the cylinder, and cutting the base in the elevation. From the points A, B', C', D', etc. draw lines $D'E'$, $C'F'$, $B'G'$, etc. at right angles to the axis $m\,n$. Make $I'E$ and $I'E'$ each equal to $I\,D$; $K'F$ and $K'F'$ each equal to $K\,C$; $L'G$ and $L'G'$ each equal to $L\,B$, etc. The curve drawn through these points will be the side projection, or side elevation, of the curve of intersection.

DRAWING PLATE, TITLE: INTERSECTIONS AND DEVELOPMENTS

48. On this plate some dimensions are given in decimal fractions instead of common fractions. Such decimal dimensions should be laid off with a decimal scale, if the student has one. A decimal scale is a scale with inches divided into tenths, hundredths, etc. If the student has no decimal scale (and such a scale is not essential), he should take the nearest value of the decimal fraction in thirty-seconds of an inch.

To change a decimal fraction to a common fraction, having a desired denominator, multiply the decimal by the desired denominator of the common fraction, and express the result as a whole number, which whole number will be the numerator of the fraction.

Thus, to express .765″ in fourths, we have $.765 \times 4 = 3.06$ fourths = say, $\frac{3}{4}$″. To express .765″ in sixteenths, we have $.765 \times 16 = 12.24$ sixteenths = say, $\frac{12}{16}$″. To express .765″ in thirty-seconds, we have $.765 \times 32 = 24.48$ thirty-seconds = say, $\frac{24}{32}$″.

The length of the circumference of a circle = the diameter $\times$ 3.1416; hence,

The length of circumference of a circle whose diameter is

$$1\tfrac{3}{8}'' = 3.1416 \times 1\tfrac{3}{8}'' = 4.32'' = 4\tfrac{5}{16}''.$$

The length of circumference of a circle whose diameter is

$$1\tfrac{1}{2}'' = 3.1416 \times 1\tfrac{1}{2}'' = 4.71'' = 4\tfrac{23}{32}''.$$

The length of circumference of a circle whose diameter is

$$1\tfrac{1}{4}'' = 3.1416 \times 1\tfrac{1}{4}'' = 3.93'' = 3\tfrac{15}{16}''.$$

The length of circumference of a circle whose diameter is

$$1\tfrac{9}{16}'' = 3.1416 \times 1\tfrac{9}{16}'' = 4.9''.$$

$$4.9'' \div 2 = 2.45'' = 2\tfrac{7}{16}''$$ (see Fig. 10).

49. This plate deals with the intersection of surfaces and their development. Fig. 1 shows the intersection of **two unequal cylindrical surfaces** whose axes *p q* and *m n* intersect at right angles. Their dimensions are given in the figure. For the sake of convenience, a bottom view is given, instead of a top view, as usual. First draw the front elevation, omitting, of course, the curve of intersection *E Q G D C B A*, which must be found. Then draw the side elevation and the bottom view, as shown. Divide the circle which represents the side projection of the cylindrical surface *F E A 1* into any convenient number of parts, in this case 12, and draw the projection lines *7 E*, *6 Q*, *5 G*, *4 D*, *3 C*, *2 B*, and *1 A* parallel to the axis *p q*. Also draw the projection lines *4–4'*, *3–3'*, *2–2'*, *1–1'*, etc. parallel to the axis *t v*. Choose a convenient point *O*, and through it draw two lines *O I* and *O K* parallel to the axes *p q* and *m n* of the cylinders. Continue the lines *4–4'*, *3–3'*, etc. downwards, until they cut *O I* in *8*, *7*, *6*, *5*, etc. Now make *O 8' = O 8*, *O 7' = O 7*, etc.; this may be most conveniently done by taking *O* as a center, and describing arcs of circles with radii equal to *O 8*, *O 7*, *O 6*, etc., cutting *O K* in *8'*, *7'*, *6'*, etc. Through *8'*, *7'*, *6'*, etc., draw the lines *8'D'*, *7'C'*, *6'B'*, etc. parallel to the center line *r s*. Through the points *D'*, *C'*, *B'*, and *A'*, draw the lines *D'D*, *C'G*, and *B'Q*, parallel to the center line *m n*, and intersecting the lines *4 D*, *5 G*, *6 Q*, *3 C*, and *2 B* in the points *D*, *G*, *Q*, etc. The curve traced through these points will be the front elevation of the curve of intersection of the two cylindrical surfaces.

Fig. 2 shows the intersection of **two equal cylindrical surfaces** at right angles to each other, as in the case of a pipe elbow. When two cylinders having *equal diameters intersect, and their axes also intersect*, the front elevation of

the curve of intersection is always a straight line, no matter what angle the two axes make with each other.

Fig. 3 shows a symmetrical **three-jointed elbow** formed by the intersection of three cylindrical surfaces. The diameter of each of the three surfaces is $1\frac{1}{2}''$. The center lines of the surfaces $R\,A\,G\,S$ and $M\,N\,P\,H$ are to be at right angles to each other; then, in order that the arrangement shall be symmetrical, the center line of the third surface $A\,M\,H\,G$ must make an angle of 45° with the center lines of the other two.

To construct the elevation as shown in the figure, draw the two center lines $m\,n$ and $p\,q$ at right angles to each other; they intersect at *6*. Lay off $6\,I = 1\frac{1}{2}''$ and draw an indefinite line $R\,S$ through I perpendicular to $m\,n$. Make $I\,R$ equal to $I\,S = 1\frac{1}{2} \times \frac{1}{2} = \frac{3}{4}''$, and draw $R\,A$ and $S\,G$ parallel to $m\,n$. Draw $O\,K$ parallel to $m\,n$ and $1\frac{1}{2}''$ below it. Through the point O, where $R\,S$ and $O\,K$ intersect, draw $O\,T$ passing through *6*, and bisect the angle $R\,O\,T$ by the line $O\,A$, which intersects $R\,A$ and $S\,G$ in A and G. Lay off $6\,J = 2\frac{1}{4}''$ and draw $P\,J\,N$ perpendicular to $p\,q$. Make $J\,P = J\,N = 1\frac{1}{2} \times \frac{1}{2} = \frac{3}{4}''$, and draw $P\,H$ and $N\,M$ parallel to $p\,q$. Draw $O\,M$ so as to bisect the angle $T\,O\,K$; $O\,M$ intersects $P\,H$ and $N\,M$ in H and M. Finally, draw $A\,M$ and $G\,H$.

Fig. 4 shows the intersection of **two unequal cylindrical surfaces** whose axes intersect at an angle of 65° instead of 90°, as in Fig. 1. The method of finding the curve of intersection is in all respects similar to that used in Fig. 1, and, as the corresponding points have been given the same letters or figures, the directions given for Fig. 1 can be applied to Fig. 4 also.

Fig. 5 shows a **cylindrical piece of iron** $2\frac{3}{16}''$ in diameter that has been gradually turned down to $1\frac{5}{16}''$ diameter, and then having the larger part flattened on two sides. The large and small parts of the piece are connected by a graceful curve. The problem is to find the curve of intersection $A\,1\,2\,3\,B$ formed by the flattening. Draw the plan and front elevation from the dimensions given; also draw

the curve $C\,6'\,5'\,4'$, and its equal on the opposite side, so that they look to the eye about as seen in the drawing. In order that all the work sent to us may be alike, the radius of this curve and the position of the center have been given on the drawing. To locate the center, draw an indefinite horizontal straight line $1'' + 1\frac{1}{16}'' = 2\frac{1}{16}''$ above the base of the piece; and with C and D as centers, and a radius of $1\frac{1}{8}''$, describe short arcs cutting the line just drawn. The points of intersection will be the required centers. With O as a center, and radii of convenient lengths, as $O\,4$, $O\,5$, $O\,6$, etc., describe arcs cutting $A'\,B'$ in $3'$, $2'$, $1'$, etc. Through the points 4, 5, 6, etc. draw the lines 4–$4'$, 5–$5'$, 6–$6'$, etc., parallel to the center line $m\,n$, and intersecting the curve $C\,4'$ in $4'$, $5'$, $6'$, C, etc. Through the points A', $1'$, $2'$, etc. draw lines $A'A$, $1'$–1, $2'$–2, etc., parallel to $m\,n$, intersecting horizontal lines drawn through C, $6'$, $5'$, $4'$, etc., in A, 1, 2, 3, etc. The points A, 1, 2, 3, etc. are points on the required curve, and through them the curve may be drawn.

Fig. 6 is the **cylindrical surface** of one section of the elbow $1\,7\,A\,G$ of Fig. 2 rolled out into a flat plate; hence, if a flat plate were cut into the same shape and size as Fig. 6 and bent into a cylinder so that the ends $1\,G'$ and $1'G''$ touch each other, the vertical projection or front elevation would be the same as shown by $1\,7\,A\,G$ in Fig. 2. If a second plate were cut out in the same manner and bent into a circle, the two pieces on being brought together, as shown in Fig. 2, would touch at every point. The problem is to find the shape of the curve $G'\,A'\,G''$. The length of the line 1–$1'$ is evidently equal to the length of the circumference of a circle whose diameter is $1\frac{3}{8}''$, or $4.32''$, very nearly. Produce the line 1–7, Fig. 2, and make 1–$1'$ equal in length to $4.32''$. Divide the circle $1\,2\,3\ldots.12$ into a convenient number of equal parts, in this case 12, and erect the perpendiculars $1\,G$, $2\,F$, $3\,E$, etc., cutting the line of intersection $G\,A$ of the cylindrical surfaces in G, F, E, etc. Divide the line 1–$1'$ into the same number of equal parts that the circle was divided into, thus making the length 1–2 equal length of arc 1–2; 2–3, length of arc 2–3, etc. Through 1,

2, *3*, etc., draw the perpendiculars *1 G'*, *2 F'*, *3 E'*, etc. and project the points *G*, *F*, *E*, etc. upon these perpendiculars, as shown, thus locating the points *G'*, *F'*, *E'*, *D'*, *C'*, *B'*, *A'* of the left-hand half of the required curve. The points on the right-hand half are found in the same manner, as shown, and the required curve can be drawn through these points.

50. A drawing like Fig. 6 is called the **development** of the cylindrical surface *1 7 A G*.

Fig. 7 is the **development of the cylindrical surface** *A G H M* of Fig. 3. Make $1\text{–}1' = 1\frac{1}{2} \times 3.1416 = 4.71''$, nearly, and divide it into 12 equal parts to correspond with the 12 equal parts into which the dotted circle is divided. Project the points *6*, *5*, etc. of the dotted circle upon *O A* as shown, thus locating the points *B*, *C*, etc. Through *B*, *C*, etc., draw *B 6*, *C 5*, etc., perpendicular to *O T*. Make $1\,G' = 1\,G''' = 1\,G$, $2\,F' = 2\,F''' = 2\,F$, $3\,E' = 3\,E''' = 3\,E$, etc. Through *G'*, *F'*, *E'*, etc., trace the curve *G' F' E'* . . . . *G''*, and, through *G'''*, *F'''*, *E'''*, etc., trace the curve *G''' F''' E'''* . . . . G^{IV}. Drawing *G' G'''* and *G'' G^{IV}* completes the figure.

Fig. 8 is the development of the cylindrical surface *1 F E A*, Fig. 1. The method used here is in all respects similar to the two preceding problems. In this case, the distances *1 A*, *7 E*, and *1' A'* are all equal to *1 A* or *E F*, in Fig. 1; and *2 B*, *6 Q*, *8 Q'*, and *12 B'* are all equal to *2 B* or *6 Q*, in Fig. 1. The development of *L M P N* is not given, for want of room, but the method will be explained in Fig. 10.

Fig. 9 is the development of the cylindrical surface *1 F E A*, Fig. 4. The student should have no difficulty in drawing this, after having studied the preceding problems.

Fig. 10 is the development of the cylindrical surface *L M P N*, Fig. 4. Owing to the want of room, only that half of the development is shown which contains the part to be cut out. The length of a circle $1\frac{9}{16}''$ in diameter is 4.9″, nearly; half of this is 2.45″. Hence, the line *Y' Y''*, Fig. 10, which equals the length of the semicircle *Y' A' Y''*, Fig. 4, is 2.45″ long. The distance *X' Y' = X'' Y''* equals the length of the cylinder, *L N* or *M P*. Lay off *X' S* equal

to the length of the arc $Y'D'$; SR equal to the arc $D'C'$; RN equal to the arc $C'B'$; NM equal to the arc $B'A'$, etc. Find the lengths of these arcs by means of the method given in connection with Fig. 54. Draw through these points the perpendiculars SS', RR', etc. With the spacing dividers, set off SD_1 equal to SD in Fig. 4; RG_1 equal to RG; NQ_1 equal to NQ; and ME_1 equal to ME. Also, $R'C_1$ equal to $R'C$; $N'B_1$ equal to $N'B$; and $M'A_1$ equal to PA. In exactly the same manner, find the points on the right-hand half of the curve. If a plate were cut of the same size and shape as shown in Fig. 10, and rolled into a semicylindrical surface, the diameter of which is $1\frac{9}{16}''$, it would exactly fit the plate cut like Fig. 9 rolled into a cylindrical surface, the diameter of which is $1\frac{1}{4}''$, the two being placed together as shown in Fig. 4.

Fig. 11 shows a **conical surface cut by a plane,** and Fig. 12 shows its **development.** Draw the elevation and horizontal projection of the base as shown in Fig. 11. Divide the projected circle (base of cone) into a convenient number of equal parts, in this case 12, and project the points *1*, *2*, *3*, etc. on the base *1'–7'*, thus locating the points *1'*, *2'*, *3'*, etc. Join these points with the apex O of the cone, by the lines $O1'$, $O2'$, $O3'$, etc., cutting the plane in A, B, C, etc. Now, choose a convenient point O, Fig. 12, and with this as a center, and a radius equal to $O1'$, or $O7'$, Fig. 11, the slant height of the cone, describe an arc *1–1'* of a circle. Make the *length of this arc* equal to the length of the circumference of a circle having the same diameter as the base of the cone. This may be conveniently done as follows: length of arc $= 2 \times 3.1416 = 6.28''$, nearly. Draw a straight line $6.28''$ long and divide it into, say, 4 equal parts. Describe an arc having a radius equal to $O1'$, the slant height of the cone, and find the length of a part of this arc equal to $6.28 \div 4 = 1.57''$ by means of the method described in connection with Fig. 53. With the dividers set for the chord of the arc just found, space off the chord four times on the longer arc *1 2 3 ....1'*, Fig. 12. Divide the arc into the same

number of equal parts that the circle *1 2 3....12* has been divided into, that is, 12 parts. Join the points of division *1*, *2*, *3*, etc. with the center *O* by the lines *O 1*, *O 2*, *O 3*, etc., as shown. Project the points *B*, *C*, *D*, etc., Fig. 11, upon *O 1'*, in B_1, C_1, D_1, etc., as shown, and lay off *O A* equal to *O A'* equal to *O A*, Fig. 11; *O B* equal to *O B'* equal to OB_1; *O C* equal to *O C'* equal to $O C_1$, etc., and through these points draw the curve. A plate cut of the same size and shape as shown by *A G A' 1' 7 1* can be bent into the conical surface shown by the elevation *A G 7' 1'*.

Particular attention must be given to the method explained above for laying out the curve of the development in Fig. 12. It would be entirely wrong to take the measurements from the lines *O F*, *O E*, *O D*, *O C*, etc., Fig. 11. The reason for this is that these lines, being on the surface of the cone, are inclined towards the observer, and so do not appear in their true lengths. The line *O D*, for example, if measured on the surface of the cone itself, would evidently be of the same length as the line OD_1; but in the figure it is much shorter. The line OD_1, however, appears in its true length in the figure, because it is not inclined to the observer in the position shown. The actual distance of point *D* from the apex *O*, therefore, is OD_1, which is the distance to be laid off for point *D* in the development. The same holds true for the other points.

SHADE LINES

51. The use of the heavy shade line will now be explained. In Fig. 71, by means of the shade lines, the draftsman knows, without looking at any other view of the object, that the rectangles *1* and *4* represent square holes, and *2* and *3*, square bosses. When he looks at the other view, it is to find the depth of the holes and the height of the bosses. This explains the use of the shade lines, viz.: to show, from that view of the drawing which is being examined, whether the part looked at is above or below the plane of the surface: that is, for example, whether

the rectangles *1*, *2*, *3*, and *4* are the tops of bosses or bottoms of holes, and, consequently, whether they extend above or below the surface of *A B D C*. In order that the shading may be uniform on all drawings, the light is assumed to come in one invariable direction, in such a manner as to be parallel to the plane of the paper, to make an angle of 45° with all horizontal and vertical lines of the drawing, and to come from the upper left-hand corner of the drawing. Each view of the object represented is shaded independently of any of the others; and, when shading, the object is always supposed to stand in such a position that the drawing will represent a top view. Any surface that can be touched by drawing a series of parallel straight lines, making an angle of 45° with the horizontal and vertical lines of the drawing, is called a **light surface**; a surface that cannot be touched by lines having this angle is called a **dark surface.** All of the edges caused by the intersection of a light and dark surface, or two dark surfaces, are usually shaded; that is, the edges thus formed are drawn in heavy lines. Exceptions to this rule are sometimes made by experienced draftsmen, when a rigid adherence to it will produce a bad effect or will render the drawing ambiguous.

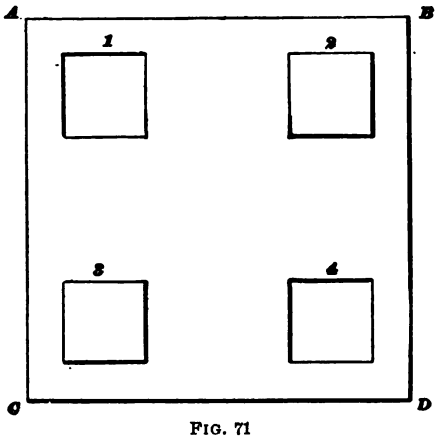


FIG. 71

Fig. 72 shows a plan of a series of triangular wedges radiating from the common center *O*. The top is, of course, a light surface, and, in order to determine whether the perpendicular surfaces are light or not, the 45° triangle may be used. Take the wedge *R O A*. A line drawn at an angle of

45°, the direction of the arrows, would strike the side of which OA is the edge; hence, this side is a light surface, and the top being also a light surface, the line OA must be light. OR, on the contrary, is a heavy line, since the light cannot strike the side of which OR is the edge without passing through the wedge. Hence, this is a dark surface, and its intersection OR with the light surface OAR requires a shaded line. For the same reason, AR is also shaded. The same reasoning as the above applies to the lines OB, OD, OG, OI, OK, and OM; also, to QN, ML, and KJ. CB is not shaded, because the light strikes the surface of which CB is the edge, as shown by the arrow, making CB the intersection of two light surfaces. ON makes an angle of exactly 45° with the horizontal, and is treated as if it were the edge of a light surface; this is done in every case in which the line considered makes an angle of 45° with the horizontal.

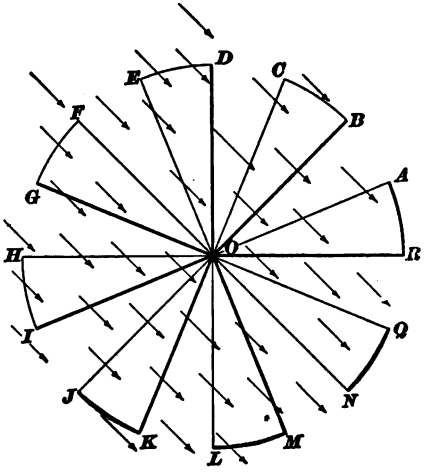


FIG. 72

In shading holes, or any parts of the drawing denoting depressions below the surface under consideration, a slightly different assumption is made. Fig. 73 shows the plan of a square block with a hexagonal hole in the center. If the light passed over the surface $ABCD$, parallel to the plane of the paper as previously assumed, all the inside surfaces would be dark, and the entire outline of the hexagon $EFGHIK$ would be shaded. In order to prevent this and make the work similar to that which has preceded, the rays of light are assumed to make an angle of 45° with the plane of the paper when shading holes and

depressions. Hence, the light will strike the surfaces whose edges are GH, HI, and IK, as shown by the arrows, leaving the surfaces whose edges are KE, EF, and FG dark as before. Therefore, these latter edges will be shaded, and the edges GH, HI, and IK will be light. See also Fig. 71.

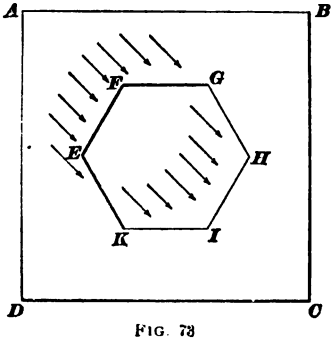


FIG. 73

The conventional method of shading circles which represent the projections of cylinders, or circular holes, is as follows: AB, Fig. 74, is the projection or end view of a cylinder having for a base the circular area AB. Draw the arrows EA and FB, making angles of 45° with the horizontal diameter, and tangent to the circle at A and B. That half of the circle in front of these two points of tangency is to be shaded, and, in order to make the drawing look well, the center point for the compasses is shifted along the line CH parallel to EA and FB in the direction of the arrow an amount equal to the thickness of the desired line. With the same radius that was used to describe the original circle, describe part of another circle, being careful not to run over the first circle, and stopping when the two lines coincide. The directions for shading a hole are precisely the same as for the projection of a cylinder base, except that the half BCA of the circle in Fig. 75 is to be shaded, the center being shifted as before, but in the opposite direction, as shown by the arrow.

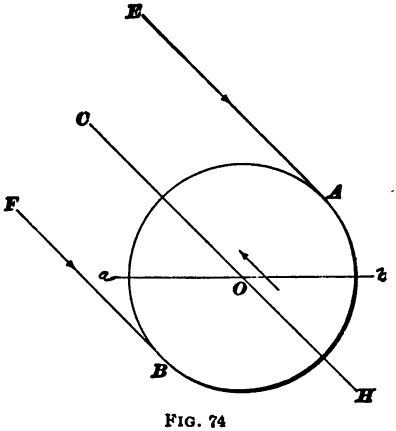


FIG. 74

Vertical projections of cylinders are shaded as shown in the front elevation of Fig. 5, Drawing Plate, title: Projections—I.

After studying the foregoing concerning shade lines, the student should be able to see the reason for the using or omitting of any shade lines on the drawings in the following plates. In the case of an object like the hexagonal prism in Fig. 6, Drawing Plate, title: Projections—I, no part of the upper base or line Se is shaded, although, strictly speaking, the part $c\,e$ of the line should be shaded; but, as this would make part of the straight line Se heavy and the greater part light, the whole line is drawn light. This is one of the exceptions previously mentioned.

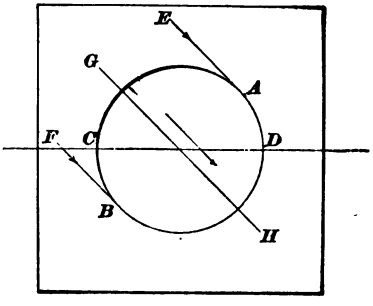


FIG. 75

A TEXTBOOK

ON

SURVEYING AND MAPPING

INTERNATIONAL CORRESPONDENCE SCHOOLS
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TABLES AND FORMULAS

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TABLES AND FORMULAS.

This volume contains all the principal Tables and Formulas which are likely to be used by the student in practice. They have been collected and placed in this volume in order to make them convenient for ready reference, so that the student will not be obliged to hunt them out. The number after each formula is the same as the number following the same formula in the text.

TABLES

OF

NATURAL SINES, COSINES TANGENTS, AND COTANGENTS

GIVING THE VALUES OF THE FUNCTIONS FOR ALL DEGREES AND MINUTES FROM

0° TO 90°

′	0°		1°		2°		3°		4°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.00000	1.	.01745	.99985	.03490	.99939	.05234	.99863	.06976	.99756	60
1	.00029	1.	.01774	.99984	.03519	.99938	.05263	.99861	.07005	.99754	59
2	.00058	1.	.01803	.99984	.03548	.99937	.05292	.99860	.07034	.99752	58
3	.00087	1.	.01832	.99983	.03577	.99936	.05321	.99858	.07063	.99750	57
4	.00116	1.	.01862	.99983	.03606	.99935	.05350	.99857	.07092	.99748	56
5	.00145	1.	.01891	.99982	.03635	.99934	.05379	.99855	.07121	.99746	55
6	.00175	1.	.01920	.99982	.03664	.99933	.05408	.99854	.07150	.99744	54
7	.00204	1.	.01949	.99981	.03693	.99932	.05437	.99852	.07179	.99742	53
8	.00233	1.	.01978	.99980	.03723	.99931	.05466	.99851	.07208	.99740	52
9	.00262	1.	.02007	.99980	.03752	.99930	.05495	.99849	.07237	.99738	51
10	.00291	1.	.02036	.99979	.03781	.99929	.05524	.99847	.07266	.99736	50
11	.00320	.99999	.02065	.99979	.03810	.99927	.05553	.99846	.07295	.99734	49
12	.00349	.99999	.02094	.99978	.03839	.99926	.05582	.99844	.07324	.99731	48
13	.00378	.99999	.02123	.99977	.03868	.99925	.05611	.99842	.07353	.99729	47
14	.00407	.99999	.02152	.99977	.03897	.99924	.05640	.99841	.07382	.99727	46
15	.00436	.99999	.02181	.99976	.03926	.99923	.05669	.99839	.07411	.99725	45
16	.00465	.99999	.02211	.99976	.03955	.99922	.05698	.99838	.07440	.99723	44
17	.00495	.99999	.02240	.99975	.03984	.99921	.05727	.99836	.07469	.99721	43
18	.00524	.99999	.02269	.99974	.04013	.99919	.05756	.99834	.07498	.99719	42
19	.00553	.99998	.02298	.99974	.04042	.99918	.05785	.99833	.07527	.99716	41
20	.00582	.99998	.02327	.99973	.04071	.99917	.05814	.99831	.07556	.99714	40
21	.00611	.99998	.02356	.99972	.04100	.99916	.05844	.99829	.07585	.99712	39
22	.00640	.99998	.02385	.99972	.04129	.99915	.05873	.99827	.07614	.99710	38
23	.00669	.99998	.02414	.99971	.04159	.99913	.05902	.99826	.07643	.99708	37
24	.00698	.99998	.02443	.99970	.04188	.99912	.05931	.99824	.07672	.99705	36
25	.00727	.99997	.02472	.99969	.04217	.99911	.05960	.99822	.07701	.99703	35
26	.00756	.99997	.02501	.99969	.04246	.99910	.05989	.99821	.07730	.99701	34
27	.00785	.99997	.02530	.99968	.04275	.99909	.06018	.99819	.07759	.99699	33
28	.00814	.99997	.02560	.99967	.04304	.99907	.06047	.99817	.07788	.99696	32
29	.00844	.99996	.02589	.99966	.04333	.99906	.06076	.99815	.07817	.99694	31
30	.00873	.99996	.02618	.99966	.04362	.99905	.06105	.99813	.07846	.99692	30
31	.00902	.99996	.02647	.99965	.04391	.99904	.06134	.99812	.07875	.99689	29
32	.00931	.99996	.02676	.99954	.04420	.99902	.06163	.99810	.07904	.99687	28
33	.00960	.99995	.02705	.99963	.04449	.99901	.06192	.99808	.07933	.99685	27
34	.00983	.99995	.02731	.99963	.04478	.99900	.06221	.99806	.07962	.99683	26
35	.01018	.99995	.02763	.99962	.04507	.99898	.06250	.99804	.07991	.99680	25
36	.01047	.99995	.02792	.99961	.04536	.99897	.06279	.99803	.08020	.99678	24
37	.01076	.99994	.02821	.99960	.04565	.99896	.06308	.99801	.08049	.99676	23
38	.01105	.99994	.02850	.99959	.04594	.99894	.06337	.99799	.08078	.99673	22
39	.01134	.99994	.02879	.99959	.04623	.99893	.06366	.99797	.08107	.99671	21
40	.01164	.99993	.02908	.99958	.04653	.99892	.06395	.99795	.08136	.99668	20
41	.01193	.99993	.02938	.99957	.04682	.99890	.06424	.99793	.08165	.99666	19
42	.01222	.99993	.02967	.99956	.04711	.99889	.06453	.99792	.08194	.99664	18
43	.01251	.99992	.02996	.99955	.04740	.99888	.06482	.99790	.08223	.99661	17
44	.01280	.99992	.03025	.99954	.04769	.99886	.06511	.99788	.08252	.99659	16
45	.01309	.99991	.03054	.99953	.04798	.99885	.06540	.99786	.08281	.99657	15
46	.01338	.99991	.03083	.99952	.04827	.99883	.06569	.99784	.08310	.99654	14
47	.01367	.99991	.03112	.99952	.04856	.99882	.06598	.99782	.08339	.99652	13
48	.01396	.99990	.03141	.99951	.04885	.99881	.06627	.99780	.08368	.99649	12
49	.01425	.99990	.03170	.99950	.04914	.99879	.06656	.99778	.08397	.99647	11
50	.01454	.99989	.03199	.99949	.04943	.99878	.06685	.99776	.08426	.99644	10
51	.01483	.99989	.03228	.99948	.04972	.99876	.06714	.99774	.08455	.99642	9
52	.01513	.99989	.03257	.99947	.05001	.99875	.06743	.99772	.08484	.99639	8
53	.01542	.99988	.03286	.99946	.05030	.99873	.06773	.99770	.08513	.99637	7
54	.01571	.99988	.03316	.99945	.05059	.99872	.06802	.99768	.08542	.99635	6
55	.01600	.99987	.03345	.99944	.05088	.99870	.06831	.99766	.08571	.99632	5
56	.01629	.99987	.03374	.99943	.05117	.99869	.06860	.99764	.08600	.99630	4
57	.01658	.99986	.03403	.99942	.05146	.99867	.06889	.99762	.08629	.99627	3
58	.01687	.99986	.03432	.99941	.05175	.99866	.06918	.99760	.08658	.99625	2
59	.01716	.99985	.03461	.99940	.05205	.99864	.06947	.99758	.08687	.99622	1
60	.01745	.99985	.03490	.99939	.05234	.99863	.06976	.99756	.08716	.99619	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	89°		88°		87°		86°		85°		

′	5°		6°		7°		8°		9°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.08716	.99619	.10453	.99452	.12187	.99255	.13917	.99027	.15643	.98769	60
1	.08745	.99617	.10482	.99449	.12216	.99251	.13946	.99023	.15672	.98764	59
2	.08774	.99614	.10511	.99446	.12245	.99248	.13975	.99019	.15701	.98760	58
3	.08803	.99612	.10540	.99443	.12274	.99244	.14004	.99015	.15730	.98755	57
4	.08831	.99609	.10569	.99440	.12302	.99240	.14033	.99011	.15758	.98751	56
5	.08860	.99607	.10597	.99437	.12331	.99237	.14061	.99006	.15787	.98746	55
6	.08889	.99604	.10626	.99434	.12360	.99233	.14090	.99002	.15816	.98741	54
7	.08918	.99602	.10655	.99431	.12389	.99230	.14119	.98998	.15845	.98737	53
8	.08947	.99599	.10684	.99428	.12418	.99226	.14148	.98994	.15873	.98732	52
9	.08976	.99596	.10713	.99424	.12447	.99222	.14177	.98990	.15902	.98728	51
10	.09005	.99594	.10742	.99421	.12476	.99219	.14205	.98986	.15931	.98723	50
11	.09034	.99591	.10771	.99418	.12504	.99215	.14234	.98982	.15959	.98718	49
12	.09063	.99588	.10800	.99415	.12533	.99211	.14263	.98978	.15988	.98714	48
13	.09092	.99586	.10829	.99412	.12562	.99208	.14292	.98973	.16017	.98709	47
14	.09121	.99583	.10858	.99409	.12591	.99204	.14320	.98969	.16046	.98704	46
15	.09150	.99580	.10887	.99406	.12620	.99200	.14349	.98965	.16074	.98700	45
16	.09179	.99578	.10916	.99402	.12649	.99197	.14378	.98961	.16103	.98695	44
17	.09208	.99575	.10945	.99399	.12678	.99193	.14407	.98957	.16132	.98690	43
18	.09237	.99572	.10973	.99396	.12706	.99189	.14436	.98953	.16160	.98686	42
19	.09266	.99570	.11002	.99393	.12735	.99186	.14464	.98948	.16189	.98681	41
20	.09295	.99567	.11031	.99390	.12764	.99182	.14493	.98944	.16218	.98676	40
21	.09324	.99564	.11060	.99386	.12793	.99178	.14522	.98940	.16246	.98671	39
22	.09353	.99562	.11089	.99383	.12822	.99175	.14551	.98936	.16275	.98667	38
23	.09382	.99559	.11118	.99380	.12851	.99171	.14580	.98931	.16304	.98662	37
24	.09411	.99556	.11147	.99377	.12880	.99167	.14608	.98927	.16333	.98657	36
25	.09440	.99553	.11176	.99374	.12908	.99163	.14637	.98923	.16361	.98652	35
26	.09469	.99551	.11205	.99370	.12937	.99160	.14666	.98919	.16390	.98648	34
27	.09498	.99548	.11234	.99367	.12966	.99156	.14695	.98914	.16419	.98643	33
28	.09527	.99545	.11263	.99364	.12995	.99152	.14723	.98910	.16447	.98638	32
29	.09556	.99542	.11291	.99360	.13024	.99148	.14752	.98906	.16476	.98633	31
30	.09585	.99540	.11320	.99357	.13053	.99144	.14781	.98902	.16505	.98629	30
31	.09614	.99537	.11349	.99354	.13081	.99141	.14810	.98897	.16533	.98624	29
32	.09642	.99534	.11378	.99351	.13110	.99137	.14838	.98893	.16562	.98619	28
33	.09671	.99531	.11407	.99347	.13139	.99133	.14867	.98889	.16591	.98614	27
34	.09700	.99528	.11436	.99344	.13168	.99129	.14896	.98884	.16620	.98609	26
35	.09729	.99526	.11465	.99341	.13197	.99125	.14925	.98880	.16648	.98604	25
36	.09758	.99523	.11494	.99337	.13226	.99122	.14954	.98876	.16677	.98600	24
37	.09787	.99520	.11523	.99334	.13254	.99118	.14982	.98871	.16706	.98595	23
38	.09816	.99517	.11552	.99331	.13283	.99114	.15011	.98867	.16734	.98590	22
39	.09845	.99514	.11580	.99327	.13312	.99110	.15040	.98863	.16763	.98585	21
40	.09874	.99511	.11609	.99324	.13341	.99106	.15069	.98858	.16792	.98580	20
41	.09903	.99508	.11638	.99320	.13370	.99102	.15097	.98854	.16820	.98575	19
42	.09932	.99506	.11667	.99317	.13399	.99098	.15126	.98849	.16849	.98570	18
43	.09961	.99503	.11696	.99314	.13427	.99094	.15155	.98845	.16878	.98565	17
44	.09990	.99500	.11725	.99310	.13456	.99091	.15184	.98841	.16906	.98561	16
45	.10019	.99497	.11754	.99307	.13485	.99087	.15212	.98836	.16935	.98556	15
46	.10048	.99494	.11783	.99303	.13514	.99083	.15241	.98832	.16964	.98551	14
47	.10077	.99491	.11812	.99300	.13543	.99079	.15270	.98827	.16992	.98546	13
48	.10106	.99488	.11840	.99297	.13572	.99075	.15299	.98823	.17021	.98541	12
49	.10135	.99485	.11869	.99293	.13600	.99071	.15327	.98818	.17050	.98536	11
50	.10164	.99482	.11898	.99290	.13629	.99067	.15356	.98814	.17078	.98531	10
51	.10192	.99479	.11927	.99286	.13658	.99063	.15385	.98809	.17107	.98526	9
52	.10221	.99476	.11956	.99283	.13687	.99059	.15414	.98805	.17136	.98521	8
53	.10250	.99473	.11985	.99279	.13716	.99055	.15442	.98800	.17164	.98516	7
54	.10279	.99470	.12014	.99276	.13744	.99051	.15471	.98796	.17193	.98511	6
55	.10308	.99467	.12043	.99272	.13773	.99047	.15500	.98791	.17222	.98506	5
56	.10337	.99464	.12071	.99269	.13802	.99043	.15529	.98787	.17250	.98501	4
57	.10366	.99461	.12100	.99265	.13831	.99039	.15557	.98782	.17279	.98496	3
58	.10395	.99458	.12129	.99262	.13860	.99035	.15586	.98778	.17308	.98491	2
59	.10424	.99455	.12158	.99258	.13889	.99031	.15615	.98773	.17336	.98486	1
60	.10453	.99452	.12187	.99255	.13917	.99027	.15643	.98769	.17365	.98481	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	84°		83°		82°		81°		80°		

′	10°		11°		12°		13°		14°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.17365	.98481	.19081	.98163	.20791	.97815	.22495	.97437	.24192	.97030	60
1	.17393	.98476	.19109	.98157	.20820	.97809	.22523	.97430	.24220	.97023	59
2	.17422	.98471	.19138	.98152	.20848	.97803	.22552	.97424	.24249	.97015	58
3	.17451	.98466	.19167	.98146	.20877	.97797	.22580	.97417	.24277	.97008	57
4	.17479	.98461	.19195	.98140	.20905	.97791	.22608	.97411	.24305	.97001	56
5	.17508	.98455	.19224	.98135	.20933	.97784	.22637	.97404	.24333	.96994	55
6	.17537	.98450	.19252	.98129	.20962	.97778	.22665	.97398	.24362	.96987	54
7	.17565	.98445	.19281	.98124	.20990	.97772	.22693	.97391	.24390	.96980	53
8	.17594	.98440	.19309	.98118	.21019	.97766	.22722	.97384	.24418	.96973	52
9	.17623	.98435	.19338	.98112	.21047	.97760	.22750	.97378	.24446	.96966	51
10	.17651	.98430	.19366	.98107	.21076	.97754	.22778	.97371	.24474	.96959	50
11	.17680	.98425	.19395	.98101	.21104	.97748	.22807	.97365	.24503	.96952	49
12	.17708	.98420	.19423	.98096	.21132	.97742	.22835	.97358	.24531	.96945	48
13	.17737	.98414	.19452	.98090	.21161	.97735	.22863	.97351	.24559	.96937	47
14	.17766	.98409	.19481	.98084	.21189	.97729	.22892	.97345	.24587	.96930	46
15	.17794	.98404	.19509	.98079	.21218	.97723	.22920	.97338	.24615	.96923	45
16	.17823	.98399	.19538	.98073	.21246	.97717	.22948	.97331	.24644	.96916	44
17	.17852	.98394	.19566	.98067	.21275	.97711	.22977	.97325	.24672	.96909	43
18	.17880	.98389	.19595	.98061	.21303	.97705	.23005	.97318	.24700	.96902	42
19	.17909	.98383	.19623	.98056	.21331	.97698	.23033	.97311	.24728	.96894	41
20	.17937	.98378	.19652	.98050	.21360	.97692	.23062	.97304	.24756	.96887	40
21	.17966	.98373	.19680	.98044	.21388	.97686	.23090	.97298	.24784	.96880	39
22	.17995	.98368	.19709	.98039	.21417	.97680	.23118	.97291	.24813	.96873	38
23	.18023	.98362	.19737	.98033	.21445	.97673	.23146	.97284	.24841	.96866	37
24	.18052	.98357	.19766	.98027	.21474	.97667	.23175	.97278	.24869	.96858	36
25	.18081	.98352	.19794	.98021	.21502	.97661	.23203	.97271	.24897	.96851	35
26	.18109	.98347	.19823	.98016	.21530	.97655	.23231	.97264	.24925	.96844	34
27	.18138	.98341	.19851	.98010	.21559	.97648	.23260	.97257	.24954	.96837	33
28	.18166	.98336	.19880	.98004	.21587	.97642	.23288	.97251	.24982	.96829	32
29	.18195	.98331	.19908	.97998	.21616	.97636	.23316	.97244	.25010	.96822	31
30	.18224	.98325	.19937	.97992	.21644	.97630	.23345	.97237	.25038	.96815	30
31	.18252	.98320	.19965	.97987	.21672	.97623	.23373	.97230	.25066	.96807	29
32	.18281	.98315	.19994	.97981	.21701	.97617	.23401	.97223	.25094	.96800	28
33	.18309	.98310	.20022	.97975	.21729	.97611	.23429	.97217	.25122	.96793	27
34	.18338	.98304	.20051	.97969	.21758	.97604	.23458	.97210	.25151	.96786	26
35	.18367	.98299	.20079	.97963	.21786	.97598	.23486	.97203	.25179	.96778	25
36	.18395	.98294	.20108	.97958	.21814	.97592	.23514	.97196	.25207	.96771	24
37	.18424	.98288	.20136	.97952	.21843	.97585	.23542	.97189	.25235	.96764	23
38	.18452	.98283	.20165	.97946	.21871	.97579	.23571	.97182	.25263	.96756	22
39	.18481	.98277	.20193	.97940	.21899	.97573	.23599	.97176	.25291	.96749	21
40	.18509	.98272	.20222	.97934	.21928	.97566	.23627	.97169	.25320	.96742	20
41	.18538	.98267	.20250	.97928	.21956	.97560	.23656	.97162	.25348	.96734	19
42	.18567	.98261	.20279	.97922	.21985	.97553	.23684	.97155	.25376	.96727	18
43	.18595	.98256	.20307	.97916	.22013	.97547	.23712	.97148	.25404	.96719	17
44	.18624	.98250	.20336	.97910	.22041	.97541	.23740	.97141	.25432	.96712	16
45	.18652	.98245	.20364	.97905	.22070	.97534	.23769	.97134	.25460	.96705	15
46	.18681	.98240	.20393	.97899	.22098	.97528	.23797	.97127	.25488	.96697	14
47	.18710	.98234	.20421	.97893	.22126	.97521	.23825	.97120	.25516	.96690	13
48	.18738	.98229	.20450	.97887	.22155	.97515	.23853	.97113	.25545	.96682	12
49	.18767	.98223	.20478	.97881	.22183	.97508	.23882	.97106	.25573	.96675	11
50	.18795	.98218	.20507	.97875	.22212	.97502	.23910	.97100	.25601	.96667	10
51	.18824	.98212	.20535	.97869	.22240	.97496	.23938	.97093	.25629	.96660	9
52	.18852	.98207	.20563	.97863	.22268	.97489	.23966	.97086	.25657	.96653	8
53	.18881	.98201	.20592	.97857	.22297	.97483	.23995	.97079	.25685	.96645	7
54	.18910	.98196	.20620	.97851	.22325	.97476	.24023	.97072	.25713	.96638	6
55	.18938	.98190	.20649	.97845	.22353	.97470	.24051	.97065	.25741	.96630	5
56	.18967	.98185	.20677	.97839	.22382	.97463	.24079	.97058	.25769	.96623	4
57	.18995	.98179	.20706	.97833	.22410	.97457	.24108	.97051	.25798	.96615	3
58	.19024	.98174	.20734	.97827	.22438	.97450	.24136	.97044	.25826	.96608	2
59	.19052	.98168	.20763	.97821	.22467	.97444	.24164	.97037	.25854	.96600	1
60	.19081	.98163	.20791	.97815	.22495	.97437	.24192	.97030	.25882	.96593	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	79°		78°		77°		76°		75°		

′	15°		16°		17°		18°		19°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.25882	.96593	.27564	.96126	.29237	.95630	.30902	.95106	.32557	.94552	60
1	.25910	.96585	.27592	.96118	.29265	.95622	.30929	.95097	.32584	.94542	59
2	.25938	.96578	.27620	.96110	.29293	.95613	.30957	.95088	.32612	.94533	58
3	.25966	.96570	.27648	.96102	.29321	.95605	.30985	.95079	.32639	.94523	57
4	.25994	.96562	.27676	.96094	.29348	.95596	.31012	.95070	.32667	.94514	56
5	.26022	.96555	.27704	.96086	.29376	.95588	.31040	.95061	.32694	.94504	55
6	.26050	.96547	.27731	.96078	.29404	.95579	.31068	.95052	.32722	.94495	54
7	.26079	.96540	.27759	.96070	.29432	.95571	.31095	.95043	.32749	.94485	53
8	.26107	.96532	.27787	.96062	.29460	.95562	.31123	.95033	.32777	.94476	52
9	.26135	.96524	.27815	.96054	.29487	.95554	.31151	.95024	.32804	.94466	51
10	.26163	.96517	.27843	.96046	.29515	.95545	.31178	.95015	.32832	.94457	50
11	.26191	.96509	.27871	.96037	.29543	.95536	.31206	.95006	.32859	.94447	49
12	.26219	.96502	.27899	.96029	.29571	.95528	.31233	.94997	.32887	.94438	48
13	.26247	.96494	.27927	.96021	.29599	.95519	.31261	.94988	.32914	.94428	47
14	.26275	.96486	.27955	.96013	.29626	.95511	.31289	.94979	.32942	.94418	46
15	.26303	.96479	.27983	.96005	.29654	.95502	.31316	.94970	.32969	.94409	45
16	.26331	.96471	.28011	.95997	.29682	.95493	.31344	.94961	.32997	.94399	44
17	.26359	.96463	.28039	.95989	.29710	.95485	.31372	.94952	.33024	.94390	43
18	.26387	.96456	.28067	.95981	.29737	.95476	.31399	.94943	.33051	.94380	42
19	.26415	.96448	.28095	.95972	.29765	.95467	.31427	.94933	.33079	.94370	41
20	.26443	.96440	.28123	.95964	.29793	.95459	.31454	.94924	.33106	.94361	40
21	.26471	.96433	.28150	.95956	.29821	.95450	.31482	.94915	.33134	.94351	39
22	.26500	.96425	.28178	.95948	.29849	.95441	.31510	.94906	.33161	.94342	38
23	.26528	.96417	.28206	.95940	.29876	.95433	.31537	.94897	.33189	.94332	37
24	.26556	.96410	.28234	.95931	.29904	.95424	.31565	.94888	.33216	.94322	36
25	.26584	.96402	.28262	.95923	.29932	.95415	.31593	.94878	.33244	.94313	35
26	.26612	.96394	.28290	.95915	.29960	.95407	.31620	.94869	.33271	.94303	34
27	.26640	.96386	.28318	.95907	.29987	.95398	.31648	.94860	.33298	.94293	33
28	.26668	.96379	.28346	.95898	.30015	.95389	.31675	.94851	.33326	.94284	32
29	.26696	.96371	.28374	.95890	.30043	.95380	.31703	.94842	.33353	.94274	31
30	.26724	.96363	.28402	.95882	.30071	.95372	.31730	.94832	.33381	.94264	30
31	.26752	.96355	.28429	.95874	.30098	.95363	.31758	.94823	.33408	.94254	29
32	.26780	.96347	.28457	.95865	.30126	.95354	.31786	.94814	.33436	.94245	28
33	.26808	.96340	.28485	.95857	.30154	.95345	.31813	.94805	.33463	.94235	27
34	.26836	.96332	.28513	.95849	.30182	.95337	.31841	.94795	.33490	.94223	26
35	.26864	.96324	.28541	.95841	.30209	.95328	.31868	.94786	.33518	.94215	25
36	.26892	.96316	.28569	.95832	.30237	.95319	.31896	.94777	.33545	.94206	24
37	.26920	.96308	.28597	.95824	.30265	.95310	.31923	.94768	.33573	.94196	23
38	.26948	.96301	.28625	.95816	.30292	.95301	.31951	.94758	.33600	.94186	22
39	.26976	.96293	.28652	.95807	.30320	.95293	.31979	.94749	.33627	.94176	21
40	.27004	.96285	.28680	.95799	.30348	.95284	.32006	.94740	.33655	.94167	20
41	.27032	.96277	.28708	.95791	.30376	.95275	.32034	.94730	.33682	.94157	19
42	.27060	.96269	.28736	.95782	.30403	.95266	.32061	.94721	.33710	.94147	18
43	.27088	.96261	.28764	.95774	.30431	.95257	.32089	.94712	.33737	.94137	17
44	.27116	.96253	.28792	.95766	.30459	.95248	.32116	.94702	.33764	.94127	16
45	.27144	.96246	.28820	.95757	.30486	.95240	.32144	.94693	.33792	.94118	15
46	.27172	.96238	.28847	.95749	.30514	.95231	.32171	.94684	.33819	.94108	14
47	.27200	.96230	.28875	.95740	.30542	.95222	.32199	.94674	.33846	.94098	13
48	.27228	.96222	.28903	.95732	.30570	.95213	.32227	.94665	.33874	.94088	12
49	.27256	.96214	.28931	.95724	.30597	.95204	.32254	.94656	.33901	.94078	11
50	.27284	.96206	.28959	.95715	.30625	.95195	.32282	.94646	.33929	.94068	10
51	.27312	.96198	.28987	.95707	.30653	.95186	.32309	.94637	.33956	.94058	9
52	.27340	.96190	.29015	.95698	.30680	.95177	.32337	.94627	.33983	.94049	8
53	.27368	.96182	.29042	.95690	.30708	.95168	.32364	.94618	.34011	.94039	7
54	.27396	.96174	.29070	.95681	.30736	.95159	.32392	.94609	.34038	.94029	6
55	.27424	.96166	.29098	.95673	.30763	.95150	.32419	.94599	.34065	.94019	5
56	.27452	.96158	.29126	.95664	.30791	.95142	.32447	.94590	.34093	.94009	4
57	.27480	.96150	.29154	.95656	.30819	.95133	.32474	.94580	.34120	.93999	3
58	.27508	.96142	.29182	.95647	.30846	.95124	.32502	.94571	.34147	.93989	2
59	.27536	.96134	.29209	.95639	.30874	.95115	.32529	.94561	.34175	.93979	1
60	.27564	.96126	.29237	.95630	.30902	.95106	.32557	.94552	.34202	.93969	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	74°		73°		72°		71°		70°		

′	20°		21°		22°		23°		24°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.34202	.93969	.35837	.93358	.37461	.92718	.39073	.92050	.40674	.91355	60
1	.34229	.93959	.35864	.93348	.37488	.92707	.39100	.92039	.40700	.91343	59
2	.34257	.93949	.35891	.93337	.37515	.92697	.39127	.92028	.40727	.91331	58
3	.34284	.93939	.35918	.93327	.37542	.92686	.39153	.92016	.40753	.91319	57
4	.34311	.93929	.35945	.93316	.37569	.92675	.39180	.92005	.40780	.91307	56
5	.34339	.93919	.35973	.93306	.37595	.92664	.39207	.91994	.40806	.91295	55
6	.34366	.93909	.36000	.93295	.37622	.92653	.39234	.91982	.40833	.91283	54
7	.34393	.93899	.36027	.93285	.37649	.92642	.39260	.91971	.40860	.91272	53
8	.34421	.93889	.36054	.93274	.37676	.92631	.39287	.91959	.40886	.91260	52
9	.34448	.93879	.36081	.93264	.37703	.92620	.39314	.91948	.40913	.91248	51
10	.34475	.93869	.36108	.93253	.37730	.92609	.39341	.91936	.40939	.91236	50
11	.34503	.93859	.36135	.93243	.37757	.92598	.39367	.91925	.40966	.91224	49
12	.34530	.93849	.36162	.93232	.37784	.92587	.39394	.91914	.40992	.91212	48
13	.34557	.93839	.36190	.93222	.37811	.92576	.39421	.91902	.41019	.91200	47
14	.34584	.93829	.36217	.93211	.37838	.92565	.39448	.91891	.41045	.91188	46
15	.34612	.93819	.36244	.93201	.37865	.92554	.39474	.91879	.41072	.91176	45
16	.34639	.93809	.36271	.93190	.37892	.92543	.39501	.91868	.41098	.91164	44
17	.34666	.93799	.36298	.93180	.37919	.92532	.39528	.91856	.41125	.91152	43
18	.34694	.93789	.36325	.93169	.37946	.92521	.39555	.91845	.41151	.91140	42
19	.34721	.93779	.36352	.93159	.37973	.92510	.39581	.91833	.41178	.91128	41
20	.34748	.93769	.36379	.93148	.37999	.92499	.39608	.91822	.41204	.91116	40
21	.34775	.93759	.36406	.93137	.38026	.92488	.39635	.91810	.41231	.91104	39
22	.34803	.93748	.36434	.93127	.38053	.92477	.39661	.91799	.41257	.91092	38
23	.34830	.93738	.36461	.93116	.38080	.92466	.39688	.91787	.41284	.91080	37
24	.34857	.93728	.36488	.93106	.38107	.92455	.39715	.91775	.41310	.91068	36
25	.34884	.93718	.36515	.93095	.38134	.92444	.39741	.91764	.41337	.91056	35
26	.34912	.93708	.36542	.93084	.38161	.92432	.39768	.91752	.41363	.91044	34
27	.34939	.93698	.36569	.93074	.38188	.92421	.39795	.91741	.41390	.91032	33
28	.34966	.93688	.36596	.93063	.38215	.92410	.39822	.91729	.41416	.91020	32
29	.34993	.93677	.36623	.93052	.38241	.92399	.39848	.91718	.41443	.91008	31
30	.35021	.93667	.36650	.93042	.38268	.92388	.39875	.91706	.41469	.90996	30
31	.35048	.93657	.36677	.93031	.38295	.92377	.39902	.91694	.41496	.90984	29
32	.35075	.93647	.36704	.93020	.38322	.92366	.39928	.91683	.41522	.90972	28
33	.35102	.93637	.36731	.93010	.38349	.92355	.39955	.91671	.41549	.90960	27
34	.35130	.93626	.36758	.92999	.38376	.92343	.39982	.91660	.41575	.90948	26
35	.35157	.93616	.36785	.92988	.38403	.92332	.40008	.91648	.41602	.90936	25
36	.35184	.93606	.36812	.92978	.38430	.92321	.40035	.91636	.41628	.90924	24
37	.35211	.93596	.36839	.92967	.38456	.92310	.40062	.91625	.41655	.90911	23
38	.35239	.93585	.36867	.92956	.38483	.92299	.40088	.91613	.41681	.90899	22
39	.35266	.93575	.36894	.92945	.38510	.92287	.40115	.91601	.41707	.90887	21
40	.35293	.93565	.36921	.92935	.38537	.92276	.40141	.91590	.41734	.90875	20
41	.35320	.93555	.36948	.92924	.38564	.92265	.40168	.91578	.41760	.90863	19
42	.35347	.93544	.36975	.92913	.38591	.92254	.40195	.91566	.41787	.90851	18
43	.35375	.93534	.37002	.92902	.38617	.92243	.40221	.91555	.41813	.90839	17
44	.35402	.93524	.37029	.92892	.38644	.92231	.40248	.91543	.41840	.90826	16
45	.35429	.93514	.37056	.92881	.38671	.92220	.40275	.91531	.41866	.90814	15
46	.35456	.93503	.37083	.92870	.38698	.92209	.40301	.91519	.41892	.90802	14
47	.35484	.93493	.37110	.92859	.38725	.92198	.40328	.91508	.41919	.90790	13
48	.35511	.93483	.37137	.92849	.38752	.92186	.40355	.91496	.41945	.90778	12
49	.35538	.93472	.37164	.92838	.38778	.92175	.40381	.91484	.41972	.90766	11
50	.35565	.93462	.37191	.92827	.38805	.92164	.40408	.91472	.41998	.90753	10
51	.35592	.93452	.37218	.92816	.38832	.92152	.40434	.91461	.42024	.90741	9
52	.35619	.93441	.37245	.92805	.38859	.92141	.40461	.91449	.42051	.90729	8
53	.35647	.93431	.37272	.92794	.38886	.92130	.40488	.91437	.42077	.90717	7
54	.35674	.93420	.37299	.92784	.38912	.92119	.40514	.91425	.42104	.90704	6
55	.35701	.93410	.37326	.92773	.38939	.92107	.40541	.91414	.42130	.90692	5
56	.35728	.93400	.37353	.92762	.38966	.92096	.40567	.91402	.42156	.90680	4
57	.35755	.93389	.37380	.92751	.38993	.92085	.40594	.91390	.42183	.90668	3
58	.35782	.93379	.37407	.92740	.39020	.92073	.40621	.91378	.42209	.90655	2
59	.35810	.93368	.37434	.92729	.39046	.92062	.40647	.91366	.42235	.90643	1
60	.35837	.93358	.37461	.92718	.39073	.92050	.40674	.91355	.42262	.90631	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	69°		68°		67°		66°		65°		

′	25°		26°		27°		28°		29°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.42262	.90631	.43837	.89879	.45399	.89101	.46947	.88295	.48481	.87462	60
1	.42288	.90618	.43863	.89867	.45425	.89087	.46973	.88281	.48506	.87448	59
2	.42315	.90606	.43889	.89854	.45451	.89074	.46999	.88267	.48532	.87434	58
3	.42341	.90594	.43916	.89841	.45477	.89061	.47024	.88254	.48557	.87420	57
4	.42367	.90582	.43942	.89828	.45503	.89048	.47050	.88240	.48583	.87406	56
5	.42394	.90569	.43968	.89816	.45529	.89035	.47076	.88226	.48608	.87391	55
6	.42420	.90557	.43994	.89803	.45554	.89021	.47101	.88213	.48634	.87377	54
7	.42446	.90545	.44020	.89790	.45580	.89008	.47127	.88199	.48659	.87363	53
8	.42473	.90532	.44046	.89777	.45606	.88995	.47153	.88185	.48684	.87349	52
9	.42499	.90520	.44072	.89764	.45632	.88981	.47178	.88172	.48710	.87335	51
10	.42525	.90507	.44098	.89752	.45658	.88968	.47204	.88158	.48735	.87321	50
11	.42552	.90495	.44124	.89739	.45684	.88955	.47229	.88144	.48761	.87306	49
12	.42578	.90483	.44151	.89726	.45710	.88942	.47255	.88130	.48786	.87292	48
13	.42604	.90470	.44177	.89713	.45736	.88928	.47281	.88117	.48811	.87278	47
14	.42631	.90458	.44203	.89700	.45762	.88915	.47306	.88103	.48837	.87264	46
15	.42657	.90446	.44229	.89687	.45787	.88902	.47332	.88089	.48862	.87250	45
16	.42683	.90433	.44255	.89674	.45813	.88888	.47358	.88075	.48888	.87235	44
17	.42709	.90421	.44281	.89662	.45839	.88875	.47383	.88062	.48913	.87221	43
18	.42736	.90408	.44307	.89649	.45865	.88862	.47409	.88048	.48938	.87207	42
19	.42762	.90396	.44333	.89636	.45891	.88848	.47434	.88034	.48964	.87193	41
20	.42788	.90383	.44359	.89623	.45917	.88835	.47460	.88020	.48989	.87178	40
21	.42815	.90371	.44385	.89610	.45942	.88822	.47486	.88006	.49014	.87164	39
22	.42841	.90358	.44411	.89597	.45968	.88808	.47511	.87993	.49040	.87150	38
23	.42867	.90346	.44437	.89584	.45994	.88795	.47537	.87979	.49065	.87136	37
24	.42894	.90334	.44464	.89571	.46020	.88782	.47562	.87965	.49090	.87121	36
25	.42920	.90321	.44490	.89558	.46046	.88768	.47588	.87951	.49116	.87107	35
26	.42946	.90309	.44516	.89545	.46072	.88755	.47614	.87937	.49141	.87093	34
27	.42972	.90296	.44542	.89532	.46097	.88741	.47639	.87923	.49166	.87079	33
28	.42999	.90284	.44568	.89519	.46123	.88728	.47665	.87909	.49192	.87064	32
29	.43025	.90271	.44594	.89506	.46149	.88715	.47690	.87896	.49217	.87050	31
30	.43051	.90259	.44620	.89493	.46175	.88701	.47716	.87882	.49242	.87036	30
31	.43077	.90246	.44646	.89480	.46201	.88688	.47741	.87868	.49268	.87021	29
32	.43104	.90233	.44672	.89467	.46226	.88674	.47767	.87854	.49293	.87007	28
33	.43130	.90221	.44698	.89454	.46252	.88661	.47793	.87840	.49318	.86993	27
34	.43156	.90208	.44724	.89441	.46278	.88647	.47818	.87826	.49344	.86978	26
35	.43182	.90196	.44750	.89428	.46304	.88634	.47844	.87812	.49369	.86964	25
36	.43209	.90183	.44776	.89415	.46330	.88620	.47869	.87798	.49394	.86949	24
37	.43235	.90171	.44802	.89402	.46355	.88607	.47895	.87784	.49419	.86935	23
38	.43261	.90158	.44828	.89389	.46381	.88593	.47920	.87770	.49445	.86921	22
39	.43287	.90146	.44854	.89376	.46407	.88580	.47946	.87756	.49470	.86906	21
40	.43313	.90133	.44880	.89363	.46433	.88566	.47971	.87743	.49495	.86892	20
41	.43340	.90120	.44906	.89350	.46458	.88553	.47997	.87729	.49521	.86878	19
42	.43366	.90108	.44932	.89337	.46484	.88539	.48022	.87715	.49546	.86863	18
43	.43392	.90095	.44958	.89324	.46510	.88526	.48048	.87701	.49571	.86849	17
44	.43418	.90082	.44984	.89311	.46536	.88512	.48073	.87687	.49596	.86834	16
45	.43445	.90070	.45010	.89298	.46561	.88499	.48099	.87673	.49622	.86820	15
46	.43471	.90057	.45036	.89285	.46587	.88485	.48124	.87659	.49647	.86805	14
47	.43497	.90045	.45062	.89272	.46613	.88472	.48150	.87645	.49672	.86791	13
48	.43523	.90032	.45088	.89259	.46639	.88458	.48175	.87631	.49697	.86777	12
49	.43549	.90019	.45114	.89245	.46664	.88445	.48201	.87617	.49723	.86762	11
50	.43575	.90007	.45140	.89232	.46690	.88431	.48226	.87603	.49748	.86748	10
51	.43602	.89994	.45166	.89219	.46716	.88417	.48252	.87589	.49773	.86733	9
52	.43628	.89981	.45192	.89206	.46742	.88404	.48277	.87575	.49798	.86719	8
53	.43654	.89968	.45218	.89193	.46767	.88390	.48303	.87561	.49824	.86704	7
54	.43680	.89956	.45243	.89180	.46793	.88377	.48328	.87546	.49849	.86690	6
55	.43706	.89943	.45269	.89167	.46819	.88363	.48354	.87532	.49874	.86675	5
56	.43733	.89930	.45295	.89153	.46844	.88349	.48379	.87518	.49899	.86661	4
57	.43759	.89918	.45321	.89140	.46870	.88336	.48405	.87504	.49924	.86646	3
58	.43785	.89905	.45347	.89127	.46896	.88322	.48430	.87490	.49950	.86632	2
59	.43811	.89892	.45373	.89114	.46921	.88308	.48456	.87476	.49975	.86617	1
60	.43837	.89879	.45399	.89101	.46947	.88295	.48481	.87462	.50000	.86603	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	64°		63°		62°		61°		60°		

′	30°		31°		32°		33°		34°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.50000	.86603	.51504	.85717	.52992	.84805	.54464	.83867	.55919	.82904	60
1	.50025	.86588	.51529	.85702	.53017	.84789	.54488	.83851	.55943	.82887	59
2	.50050	.86573	.51554	.85687	.53041	.84774	.54513	.83835	.55968	.82871	58
3	.50076	.86559	.51579	.85672	.53066	.84759	.54537	.83819	.55992	.82855	57
4	.50101	.86544	.51604	.85657	.53091	.84743	.54561	.83804	.56016	.82839	56
5	.50126	.86530	.51628	.85642	.53115	.84728	.54586	.83788	.56040	.82822	55
6	.50151	.86515	.51653	.85627	.53140	.84712	.54610	.83772	.56064	.82806	54
7	.50176	.86501	.51678	.85612	.53164	.84697	.54635	.83756	.56088	.82790	53
8	.50201	.86486	.51703	.85597	.53189	.84681	.54659	.83740	.56112	.82773	52
9	.50227	.86471	.51728	.85582	.53214	.84666	.54683	.83724	.56136	.82757	51
10	.50252	.86457	.51753	.85567	.53238	.84650	.54708	.83708	.56160	.82741	50
11	.50277	.86442	.51778	.85551	.53263	.84635	.54732	.83692	.56184	.82724	49
12	.50302	.86427	.51803	.85536	.53288	.84619	.54756	.83676	.56208	.82708	48
13	.50327	.86413	.51828	.85521	.53312	.84604	.54781	.83660	.56232	.82692	47
14	.50352	.86398	.51852	.85506	.53337	.84588	.54805	.83645	.56256	.82675	46
15	.50377	.86384	.51877	.85491	.53361	.84573	.54829	.83629	.56280	.82659	45
16	.50403	.86369	.51902	.85476	.53386	.84557	.54854	.83613	.56305	.82643	44
17	.50428	.86354	.51927	.85461	.53411	.84542	.54878	.83597	.56329	.82626	43
18	.50453	.86340	.51952	.85446	.53435	.84526	.54902	.83581	.56353	.82610	42
19	.50478	.86325	.51977	.85431	.53460	.84511	.54927	.83565	.56377	.82593	41
20	.50503	.86310	.52002	.85416	.53484	.84495	.54951	.83549	.56401	.82577	40
21	.50528	.86295	.52026	.85401	.53509	.84480	.54975	.83533	.56425	.82561	39
22	.50553	.86281	.52051	.85385	.53534	.84464	.54999	.83517	.56449	.82544	38
23	.50578	.86266	.52076	.85370	.53558	.84448	.55024	.83501	.56473	.82528	37
24	.50603	.86251	.52101	.85355	.53583	.84433	.55048	.83485	.56497	.82511	36
25	.50628	.86237	.52126	.85340	.53607	.84417	.55072	.83469	.56521	.82495	35
26	.50654	.86222	.52151	.85325	.53632	.84402	.55097	.83453	.56545	.82478	34
27	.50679	.86207	.52175	.85310	.53656	.84386	.55121	.83437	.56569	.82462	33
28	.50704	.86192	.52200	.85294	.53681	.84370	.55145	.83421	.56593	.82446	32
29	.50729	.86178	.52225	.85279	.53705	.84355	.55169	.83405	.56617	.82429	31
30	.50754	.86163	.52250	.85264	.53730	.84339	.55194	.83389	.56641	.82413	30
31	.50779	.86148	.52275	.85249	.53754	.84324	.55218	.83373	.56665	.82396	29
32	.50804	.86133	.52299	.85234	.53779	.84308	.55242	.83356	.56689	.82380	28
33	.50829	.86119	.52324	.85218	.53804	.84292	.55266	.83340	.56713	.82363	27
34	.50854	.86104	.52349	.85203	.53828	.84277	.55291	.83324	.56736	.82347	26
35	.50879	.86089	.52374	.85188	.53853	.84261	.55315	.83308	.56760	.82330	25
36	.50904	.86074	.52399	.85173	.53877	.84245	.55339	.83292	.56784	.82314	24
37	.50929	.86059	.52423	.85157	.53902	.84230	.55363	.83276	.56808	.82297	23
38	.50954	.86045	.52448	.85142	.53926	.84214	.55388	.83260	.56832	.82281	22
39	.50979	.86030	.52473	.85127	.53951	.84198	.55412	.83244	.56856	.82264	21
40	.51004	.86015	.52498	.85112	.53975	.84182	.55436	.83228	.56880	.82248	20
41	.51029	.86000	.52522	.85096	.54000	.84167	.55460	.83212	.56904	.82231	19
42	.51054	.85985	.52547	.85081	.54024	.84151	.55484	.83195	.56928	.82214	18
43	.51079	.85970	.52572	.85066	.54049	.84135	.55509	.83179	.56952	.82198	17
44	.51104	.85956	.52597	.85051	.54073	.84120	.55533	.83163	.56976	.82181	16
45	.51129	.85941	.52621	.85035	.54097	.84104	.55557	.83147	.57000	.82165	15
46	.51154	.85926	.52646	.85020	.54122	.84088	.55581	.83131	.57024	.82148	14
47	.51179	.85911	.52671	.85005	.54146	.84072	.55605	.83115	.57047	.82132	13
48	.51204	.85896	.52696	.84989	.54171	.84057	.55630	.83098	.57071	.82115	12
49	.51229	.85881	.52720	.84974	.54195	.84041	.55654	.83082	.57095	.82098	11
50	.51254	.85866	.52745	.84959	.54220	.84025	.55678	.83066	.57119	.82082	10
51	.51279	.85851	.52770	.84943	.54244	.84009	.55702	.83050	.57143	.82065	9
52	.51304	.85836	.52794	.84928	.54269	.83994	.55726	.83034	.57167	.82048	8
53	.51329	.85821	.52819	.84913	.54293	.83978	.55750	.83017	.57191	.82032	7
54	.51354	.85806	.52844	.84897	.54317	.83962	.55775	.83001	.57215	.82015	6
55	.51379	.85792	.52869	.84882	.54342	.83946	.55799	.82985	.57238	.81999	5
56	.51404	.85777	.52893	.84866	.54366	.83930	.55823	.82969	.57262	.81982	4
57	.51429	.85762	.52918	.84851	.54391	.83915	.55847	.82953	.57286	.81965	3
58	.51454	.85747	.52943	.84836	.54415	.83899	.55871	.82936	.57310	.81949	2
59	.51479	.85732	.52967	.84820	.54440	.83883	.55895	.82920	.57334	.81932	1
60	.51504	.85717	.52992	.84805	.54464	.83867	.55919	.82904	.57358	.81915	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	59°		58°		57°		56°		55°		

′	35°		36°		37°		38°		39°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.57358	.81915	.58779	.80902	.60182	.79864	.61566	.78801	.62932	.77715	60
1	.57381	.81899	.58802	.80885	.60205	.79846	.61589	.78783	.62955	.77696	59
2	.57405	.81882	.58826	.80867	.60228	.79829	.61612	.78765	.62977	.77678	58
3	.57429	.81865	.58849	.80850	.60251	.79811	.61635	.78747	.63000	.77660	57
4	.57453	.81848	.58873	.80833	.60274	.79793	.61658	.78729	.63022	.77641	56
5	.57477	.81832	.58896	.80816	.60298	.79776	.61681	.78711	.63045	.77623	55
6	.57501	.81815	.58920	.80799	.60321	.79758	.61704	.78694	.63068	.77605	54
7	.57524	.81798	.58943	.80782	.60344	.79741	.61726	.78676	.63090	.77586	53
8	.57548	.81782	.58967	.80765	.60367	.79723	.61749	.78658	.63113	.77568	52
9	.57572	.81765	.58990	.80748	.60390	.79706	.61772	.78640	.63135	.77550	51
10	.57596	.81748	.59014	.80730	.60414	.79688	.61795	.78622	.63158	.77531	50
11	.57619	.81731	.59037	.80713	.60437	.79671	.61818	.78604	.63180	.77513	49
12	.57643	.81714	.59061	.80696	.60460	.79653	.61841	.78586	.63203	.77494	48
13	.57667	.81698	.59084	.80679	.60483	.79635	.61864	.78568	.63225	.77476	47
14	.57691	.81681	.59108	.80662	.60506	.79618	.61887	.78550	.63248	.77458	46
15	.57715	.81664	.59131	.80644	.60529	.79600	.61909	.78532	.63271	.77439	45
16	.57738	.81647	.59154	.80627	.60553	.79583	.61932	.78514	.63293	.77421	44
17	.57762	.81631	.59178	.80610	.60576	.79565	.61955	.78496	.63316	.77402	43
18	.57786	.81614	.59201	.80593	.60599	.79547	.61978	.78478	.63338	.77384	42
19	.57810	.81597	.59225	.80576	.60622	.79530	.62001	.78460	.63361	.77366	41
20	.57833	.81580	.59248	.80558	.60645	.79512	.62024	.78442	.63383	.77347	40
21	.57857	.81563	.59272	.80541	.60668	.79494	.62046	.78424	.63406	.77329	39
22	.57881	.81546	.59295	.80524	.60691	.79477	.62069	.78405	.63428	.77310	38
23	.57904	.81530	.59318	.80507	.60714	.79459	.62092	.78387	.63451	.77292	37
24	.57928	.81513	.59342	.80489	.60738	.79441	.62115	.78369	.63473	.77273	36
25	.57952	.81496	.59365	.80472	.60761	.79424	.62138	.78351	.63496	.77255	35
26	.57976	.81479	.59389	.80455	.60784	.79406	.62160	.78333	.63518	.77236	34
27	.57999	.81462	.59412	.80438	.60807	.79388	.62183	.78315	.63540	.77218	33
28	.58023	.81445	.59436	.80420	.60830	.79371	.62206	.78297	.63563	.77199	32
29	.58047	.81428	.59459	.80403	.60853	.79353	.62229	.78279	.63585	.77181	31
30	.58070	.81412	.59482	.80386	.60876	.79335	.62251	.78261	.63608	.77162	30
31	.58094	.81395	.59506	.80368	.60899	.79318	.62274	.78243	.63630	.77144	29
32	.58118	.81378	.59529	.80351	.60922	.79300	.62297	.78225	.63653	.77125	28
33	.58141	.81361	.59552	.80334	.60945	.79282	.62320	.78206	.63675	.77107	27
34	.58165	.81344	.59576	.80316	.60968	.79264	.62342	.78188	.63698	.77088	26
35	.58189	.81327	.59599	.80299	.60991	.79247	.62365	.78170	.63720	.77070	25
36	.58212	.81310	.59622	.80282	.61015	.79229	.62388	.78152	.63742	.77051	24
37	.58236	.81293	.59646	.80264	.61038	.79211	.62411	.78134	.63765	.77033	23
38	.58260	.81276	.59669	.80247	.61061	.79193	.62433	.78116	.63787	.77014	22
39	.58283	.81259	.59693	.80230	.61084	.79176	.62456	.78098	.63810	.76996	21
40	.58307	.81242	.59716	.80212	.61107	.79158	.62479	.78079	.63832	.76977	20
41	.58330	.81225	.59739	.80195	.61130	.79140	.62502	.78061	.63854	.76959	19
42	.58354	.81208	.59763	.80178	.61153	.79122	.62524	.78043	.63877	.76940	18
43	.58378	.81191	.59786	.80160	.61176	.79105	.62547	.78025	.63899	.76921	17
44	.58401	.81174	.59809	.80143	.61199	.79087	.62570	.78007	.63922	.76903	16
45	.58425	.81157	.59832	.80125	.61222	.79069	.62592	.77988	.63944	.76884	15
46	.58449	.81140	.59856	.80108	.61245	.79051	.62615	.77970	.63966	.76866	14
47	.58472	.81123	.59879	.80091	.61268	.79033	.62638	.77952	.63989	.76847	13
48	.58496	.81106	.59902	.80073	.61291	.79016	.62660	.77934	.64011	.76828	12
49	.58519	.81089	.59926	.80056	.61314	.78998	.62683	.77916	.64033	.76810	11
50	.58543	.81072	.59949	.80038	.61337	.78980	.62706	.77897	.64056	.76791	10
51	.58567	.81055	.59972	.80021	.61360	.78962	.62728	.77879	.64078	.76772	9
52	.58590	.81038	.59995	.80003	.61383	.78944	.62751	.77861	.64100	.76754	8
53	.58614	.81021	.60019	.79986	.61406	.78926	.62774	.77843	.64123	.76735	7
54	.58637	.81004	.60042	.79968	.61429	.78908	.62796	.77824	.64145	.76717	6
55	.58661	.80987	.60065	.79951	.61451	.78891	.62819	.77806	.64167	.76698	5
56	.58684	.80970	.60089	.79934	.61474	.78873	.62842	.77788	.64190	.76679	4
57	.58708	.80953	.60112	.79916	.61497	.78855	.62864	.77769	.64212	.76661	3
58	.58731	.80936	.60135	.79899	.61520	.78837	.62887	.77751	.64234	.76642	2
59	.58755	.80919	.60158	.79881	.61543	.78819	.62909	.77733	.64256	.76623	1
60	.58779	.80902	.60182	.79864	.61566	.78801	.62932	.77715	.64279	.76604	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	54°		53°		52°		51°		50°		

′	40°		41°		42°		43°		44°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.64279	.76604	.65606	.75471	.66913	.74314	.68200	.73135	.69466	.71934	60
1	.64301	.76586	.65628	.75452	.66935	.74295	.68221	.73116	.69487	.71914	59
2	.64323	.76567	.65650	.75433	.66956	.74276	.68242	.73096	.69508	.71894	58
3	.64346	.76548	.65672	.75414	.66978	.74256	.68264	.73076	.69529	.71873	57
4	.64368	.76530	.65694	.75395	.66999	.74237	.68285	.73056	.69549	.71853	56
5	.64390	.76511	.65716	.75375	.67021	.74217	.68306	.73036	.69570	.71833	55
6	.64412	.76492	.65738	.75356	.67043	.74198	.68327	.73016	.69591	.71813	54
7	.64435	.76473	.65759	.75337	.67064	.74178	.68349	.72996	.69612	.71792	53
8	.64457	.76455	.65781	.75318	.67086	.74159	.68370	.72976	.69633	.71772	52
9	.64479	.76436	.65803	.75299	.67107	.74139	.68391	.72957	.69654	.71752	51
10	.64501	.76417	.65825	.75280	.67129	.74120	.68412	.72937	.69675	.71732	50
11	.64524	.76398	.65847	.75261	.67151	.74100	.68434	.72917	.69696	.71711	49
12	.64546	.76380	.65869	.75241	.67172	.74080	.68455	.72897	.69717	.71691	48
13	.64568	.76361	.65891	.75222	.67194	.74061	.68476	.72877	.69737	.71671	47
14	.64590	.76342	.65913	.75203	.67215	.74041	.68497	.72857	.69758	.71650	46
15	.64612	.76323	.65935	.75184	.67237	.74022	.68518	.72837	.69779	.71630	45
16	.64635	.76304	.65956	.75165	.67258	.74002	.68539	.72817	.69800	.71610	44
17	.64657	.76286	.65978	.75146	.67280	.73983	.68561	.72797	.69821	.71590	43
18	.64679	.76267	.66000	.75126	.67301	.73963	.68582	.72777	.69842	.71569	42
19	.64701	.76248	.66022	.75107	.67323	.73944	.68603	.72757	.69862	.71549	41
20	.64723	.76229	.66044	.75088	.67344	.73924	.68624	.72737	.69883	.71529	40
21	.64746	.76210	.66066	.75069	.67366	.73904	.68645	.72717	.69904	.71508	39
22	.64768	.76192	.66088	.75050	.67387	.73885	.68666	.72697	.69925	.71488	38
23	.64790	.76173	.66109	.75030	.67409	.73865	.68688	.72677	.69946	.71468	37
24	.64812	.76154	.66131	.75011	.67430	.73846	.68709	.72657	.69966	.71447	36
25	.64834	.76135	.66153	.74992	.67452	.73826	.68730	.72637	.69987	.71427	35
26	.64856	.76116	.66175	.74973	.67473	.73806	.68751	.72617	.70008	.71407	34
27	.64878	.76097	.66197	.74953	.67495	.73787	.68772	.72597	.70029	.71386	33
28	.64901	.76078	.66218	.74934	.67516	.73767	.68793	.72577	.70049	.71366	32
29	.64923	.76059	.66240	.74915	.67538	.73747	.68814	.72557	.70070	.71345	31
30	.64945	.76041	.66262	.74896	.67559	.73728	.68835	.72537	.70091	.71325	30
31	.64967	.76022	.66284	.74876	.67580	.73708	.68857	.72517	.70112	.71305	29
32	.64989	.76003	.66306	.74857	.67602	.73688	.68878	.72497	.70132	.71284	28
33	.65011	.75984	.66327	.74838	.67623	.73669	.68899	.72477	.70153	.71264	27
34	.65033	.75965	.66349	.74818	.67645	.73649	.68920	.72457	.70174	.71243	26
35	.65055	.75946	.66371	.74799	.67666	.73629	.68941	.72437	.70195	.71223	25
36	.65077	.75927	.66393	.74780	.67688	.73610	.68962	.72417	.70215	.71203	24
37	.65100	.75908	.66414	.74760	.67709	.73590	.68983	.72397	.70236	.71182	23
38	.65122	.75889	.66436	.74741	.67730	.73570	.69004	.72377	.70257	.71162	22
39	.65144	.75870	.66458	.74722	.67752	.73551	.69025	.72357	.70277	.71141	21
40	.65166	.75851	.66480	.74703	.67773	.73531	.69046	.72337	.70298	.71121	20
41	.65188	.75832	.66501	.74683	.67795	.73511	.69067	.72317	.70319	.71100	19
42	.65210	.75813	.66523	.74664	.67816	.73491	.69088	.72297	.70339	.71080	18
43	.65232	.75794	.66545	.74644	.67837	.73472	.69109	.72277	.70360	.71059	17
44	.65254	.75775	.66566	.74625	.67859	.73452	.69130	.72257	.70381	.71039	16
45	.65276	.75756	.66588	.74606	.67880	.73432	.69151	.72236	.70401	.71019	15
46	.65298	.75738	.66610	.74586	.67901	.73413	.69172	.72216	.70422	.70998	14
47	.65320	.75719	.66632	.74567	.67923	.73393	.69193	.72196	.70443	.70978	13
48	.65342	.75700	.66653	.74548	.67944	.73373	.69214	.72176	.70463	.70957	12
49	.65364	.75680	.66675	.74528	.67965	.73353	.69235	.72156	.70484	.70937	11
50	.65386	.75661	.66697	.74509	.67987	.73333	.69256	.72136	.70505	.70916	10
51	.65408	.75642	.66718	.74489	.68008	.73314	.69277	.72116	.70525	.70896	9
52	.65430	.75623	.66740	.74470	.68029	.73294	.69298	.72095	.70546	.70875	8
53	.65452	.75604	.66762	.74451	.68051	.73274	.69319	.72075	.70567	.70855	7
54	.65474	.75585	.66783	.74431	.68072	.73254	.69340	.72055	.70587	.70834	6
55	.65496	.75566	.66805	.74412	.68093	.73234	.69361	.72035	.70608	.70813	5
56	.65518	.75547	.66827	.74392	.68115	.73215	.69382	.72015	.70628	.70793	4
57	.65540	.75528	.66848	.74373	.68136	.73195	.69403	.71995	.70649	.70772	3
58	.65562	.75509	.66870	.74353	.68157	.73175	.69424	.71974	.70670	.70752	2
59	.65584	.75490	.66891	.74334	.68179	.73155	.69445	.71954	.70690	.70731	1
60	.65606	.75471	.66913	.74314	.68200	.73135	.69466	.71934	.70711	.70711	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	49°		48°		47°		46°		45°		

′	0°		1°		2°		3°		4°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.00000	Infin.	.01746	57.2900	.03492	28.6363	.05241	19.0811	.06993	14.3007	60
1	.00029	3437.75	.01775	56.3506	.03521	28.3994	.05270	18.9755	.07022	14.2411	59
2	.00058	1718.87	.01804	55.4415	.03550	28.1664	.05299	18.8711	.07051	14.1821	58
3	.00087	1145.92	.01833	54.5613	.03579	27.9372	.05328	18.7678	.07080	14.1235	57
4	.00116	859.436	.01862	53.7086	.03609	27.7117	.05357	18.6656	.07110	14.0655	56
5	.00145	687.549	.01891	52.8821	.03638	27.4899	.05387	18.5645	.07139	14.0079	55
6	.00175	572.957	.01920	52.0807	.03667	27.2715	.05416	18.4645	.07168	13.9507	54
7	.00204	491.106	.01949	51.3032	.03696	27.0566	.05445	18.3655	.07197	13.8940	53
8	.00233	429.718	.01978	50.5485	.03725	26.8450	.05474	18.2677	.07227	13.8378	52
9	.00262	381.971	.02007	49.8157	.03754	26.6367	.05503	18.1708	.07256	13.7821	51
10	.00291	343.774	.02036	49.1039	.03783	26.4316	.05533	18.0750	.07285	13.7267	50
11	.00320	312.521	.02066	48.4121	.03812	26.2296	.05562	17.9802	.07314	13.6719	49
12	.00349	286.478	.02095	47.7395	.03842	26.0307	.05591	17.8863	.07344	13.6174	48
13	.00378	264.441	.02124	47.0853	.03871	25.8348	.05620	17.7934	.07373	13.5634	47
14	.00407	245.552	.02153	46.4489	.03900	25.6418	.05649	17.7015	.07402	13.5098	46
15	.00436	229.182	.02182	45.8294	.03929	25.4517	.05678	17.6106	.07431	13.4566	45
16	.00465	214.858	.02211	45.2261	.03958	25.2644	.05708	17.5205	.07461	13.4039	44
17	.00495	202.219	.02240	44.6386	.03987	25.0798	.05737	17.4314	.07490	13.3515	43
18	.00524	190.984	.02269	44.0661	.04016	24.8978	.05766	17.3432	.07519	13.2996	42
19	.00553	180.932	.02298	43.5081	.04046	24.7185	.05795	17.2558	.07548	13.2480	41
20	.00582	171.885	.02328	42.9641	.04075	24.5418	.05824	17.1693	.07578	13.1969	40
21	.00611	163.700	.02357	42.4335	.04104	24.3675	.05854	17.0837	.07607	13.1461	39
22	.00640	156.259	.02386	41.9158	.04133	24.1957	.05883	16.9990	.07636	13.0958	38
23	.00669	149.465	.02415	41.4106	.04162	24.0263	.05912	16.9150	.07665	13.0458	37
24	.00698	143.237	.02444	40.9174	.04191	23.8593	.05941	16.8319	.07695	12.9962	36
25	.00727	137.507	.02473	40.4358	.04220	23.6945	.05970	16.7496	.07724	12.9469	35
26	.00756	132.219	.02502	39.9655	.04250	23.5321	.05999	16.6681	.07753	12.8981	34
27	.00785	127.321	.02531	39.5059	.04279	23.3718	.06029	16.5874	.07782	12.8496	33
28	.00815	122.774	.02560	39.0568	.04308	23.2137	.06058	16.5075	.07812	12.8014	32
29	.00844	118.540	.02589	38.6177	.04337	23.0577	.06087	16.4283	.07841	12.7536	31
30	.00873	114.589	.02619	38.1885	.04366	22.9038	.06116	16.3499	.07870	12.7062	30
31	.00902	110.892	.02648	37.7686	.04395	22.7519	.06145	16.2722	.07899	12.6591	29
32	.00931	107.426	.02677	37.3579	.04424	22.6020	.06175	16.1952	.07929	12.6124	28
33	.00960	104.171	.02706	36.9560	.04454	22.4541	.06204	16.1190	.07958	12.5660	27
34	.00989	101.107	.02735	36.5627	.04483	22.3081	.06233	16.0435	.07987	12.5199	26
35	.01018	98.2179	.02764	36.1776	.04512	22.1640	.06262	15.9687	.08017	12.4742	25
36	.01047	95.4895	.02793	35.8006	.04541	22.0217	.06291	15.8945	.08046	12.4288	24
37	.01076	92.9085	.02822	35.4313	.04570	21.8813	.06321	15.8211	.08075	12.3838	23
38	.01105	90.4633	.02851	35.0695	.04599	21.7426	.06350	15.7483	.08104	12.3390	22
39	.01135	88.1436	.02881	34.7151	.04628	21.6056	.06379	15.6762	.08134	12.2946	21
40	.01164	85.9398	.02910	34.3678	.04658	21.4704	.06408	15.6048	.08163	12.2505	20
41	.01193	83.8435	.02939	34.0273	.04687	21.3369	.06437	15.5340	.08192	12.2067	19
42	.01222	81.8470	.02968	33.6935	.04716	21.2049	.06467	15.4638	.08221	12.1632	18
43	.01251	79.9434	.02997	33.3662	.04745	21.0747	.06496	15.3943	.08251	12.1201	17
44	.01280	78.1263	.03026	33.0452	.04774	20.9460	.06525	15.3254	.08280	12.0772	16
45	.01309	76.3900	.03055	32.7303	.04803	20.8188	.06554	15.2571	.08309	12.0346	15
46	.01338	74.7292	.03084	32.4213	.04833	20.6932	.06584	15.1893	.08339	11.9923	14
47	.01367	73.1390	.03114	32.1181	.04862	20.5691	.06613	15.1222	.08368	11.9504	13
48	.01396	71.6151	.03143	31.8205	.04891	20.4465	.06642	15.0557	.08397	11.9087	12
49	.01425	70.1533	.03172	31.5284	.04920	20.3253	.06671	14.9898	.08427	11.8673	11
50	.01455	68.7501	.03201	31.2416	.04949	20.2056	.06700	14.9244	.08456	11.8262	10
51	.01484	67.4019	.03230	30.9599	.04978	20.0872	.06730	14.8596	.08485	11.7853	9
52	.01513	66.1055	.03259	30.6833	.05007	19.9702	.06759	14.7954	.08514	11.7448	8
53	.01542	64.8580	.03288	30.4116	.05037	19.8546	.06788	14.7317	.08544	11.7045	7
54	.01571	63.6567	.03317	30.1446	.05066	19.7403	.06817	14.6685	.08573	11.6645	6
55	.01600	62.4992	.03346	29.8823	.05095	19.6273	.06847	14.6059	.08602	11.6248	5
56	.01629	61.3829	.03376	29.6245	.05124	19.5156	.06876	14.5438	.08632	11.5853	4
57	.01658	60.3058	.03405	29.3711	.05153	19.4051	.06905	14.4823	.08661	11.5461	3
58	.01687	59.2659	.03434	29.1220	.05182	19.2959	.06934	14.4212	.08690	11.5072	2
59	.01716	58.2612	.03463	28.8771	.05212	19.1879	.06963	14.3607	.08720	11.4685	1
60	.01746	57.2900	.03402	28.6363	.05241	19.0811	.06993	14.3007	.08749	11.4301	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	89°		88°		87°		86°		85°		

′	5°		6°		7°		8°		9°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.08749	11.4301	.10510	9.51436	.12278	8.14435	.14054	7.11537	.15838	6.31375	60
1	.08778	11.3919	.10540	9.48781	.12308	8.12481	.14084	7.10038	.15868	6.30189	59
2	.08807	11.3540	.10569	9.46141	.12338	8.10536	.14113	7.08546	.15898	6.29007	58
3	.08837	11.3163	.10599	9.43515	.12367	8.08600	.14143	7.07059	.15928	6.27829	57
4	.08866	11.2789	.10628	9.40904	.12397	8.06674	14173	7.05579	.15958	6.26655	56
5	.08895	11.2417	.10657	9.38307	.12426	8.04756	.14202	7.04105	.15988	6.25486	55
6	.08925	11.2048	.10687	9.35724	.12456	8.02848	.14232	7.02637	.16017	6.24321	54
7	.08954	11.1681	.10716	9.33155	.12485	8.00948	.14262	7.01174	.16047	6.23160	53
8	.08983	11.1316	.10746	9.30599	.12515	7.99058	.14291	6.99718	.16077	6.22003	52
9	.09013	11.0954	.10775	9.28058	.12544	7.97176	.14321	6.98268	.16107	6.20851	51
10	.09042	11.0594	.10805	9.25530	.12574	7.95302	.14351	6.96823	.16137	6.19703	50
11	.09071	11.0237	.10834	9.23016	.12603	7.93438	.14381	6.95385	.16167	6.18559	49
12	.09101	10.9882	.10863	9.20516	.12633	7.91582	.14410	6.93952	.16196	6.17419	48
13	.09130	10.9529	.10893	9.18028	.12662	7.89734	.14440	6.92525	.16226	6.16283	47
14	.09159	10.9178	.10922	9.15554	.12692	7.87895	.14470	6.91104	.16256	6.15151	46
15	.09189	10.8829	.10952	9.13093	.12722	7.86064	.14499	6.89688	.16286	6.14023	45
16	.09218	10.8483	.10981	9.10646	.12751	7.84242	.14529	6.88278	.16316	6.12899	44
17	.09247	10.8139	.11011	9.08211	.12781	7.82428	.14559	6.86874	.16346	6.11779	43
18	.09277	10.7797	.11040	9.05789	.12810	7.80622	.14588	6.85475	.16376	6.10664	42
19	.09306	10.7457	.11070	9.03379	.12840	7.78825	.14618	6.84082	.16405	6.09552	41
20	.09335	10.7119	.11099	9.00983	.12869	7.77035	.14648	6.82694	.16435	6.08444	40
21	.09365	10.6783	.11128	8.98598	.12899	7.75254	.14678	6.81812	.16465	6.07340	39
22	.09394	10.6450	.11158	8.96227	.12929	7.73480	.14707	6.79936	.16495	6.06240	38
23	.09423	10.6118	.11187	8.93867	.12958	7.71715	.14737	6.78564	.16525	6.05143	37
24	.09453	10.5789	.11217	8.91520	.12988	7.69957	.14767	6.77199	.16555	6.04051	36
25	.09482	10.5462	.11246	8.89185	.13017	7.68208	.14796	6.75838	.16585	6.02962	35
26	.09511	10.5136	.11276	8.86862	.13047	7.66466	.14826	6.74483	.16615	6.01878	34
27	.09541	10.4813	.11305	8.84551	.13076	7.64732	.14856	6.73133	.16645	6.00797	33
28	.09570	10.4491	.11335	8.82252	.13106	7.63005	.14886	6.71789	.16674	5.99720	32
29	.09600	10.4172	.11364	8.79964	.13136	7.61287	.14915	6.70450	.16704	5.98646	31
30	.09629	10.3854	.11394	8.77689	.13165	7.59575	.14945	6.69116	.16734	5.97576	30
31	.09658	10.3538	.11423	8.75425	.13195	7.57872	.14975	6.67787	.16764	5.96510	29
32	.09688	10.3224	.11452	8.73172	.13224	7.56176	.15005	6.66463	.16794	5.95448	28
33	.09717	10.2913	.11482	8.70931	.13254	7.54487	.15034	6.65144	.16824	5.94390	27
34	.09746	10.2602	.11511	8.68701	.13284	7.52806	.15064	6.63831	.16854	5.93335	26
35	.09776	10.2294	.11541	8.66482	.13313	7.51132	.15094	6.62523	.16884	5.92283	25
36	.09805	10.1988	.11570	8.64275	.13343	7.49465	.15124	6.61219	.16914	5.91236	24
37	.09834	10.1683	.11600	8.62078	.13372	7.47806	.15153	6.59921	.16944	5 90191	23
38	.09864	10.1381	.11629	8.59893	.13402	7.46154	.15183	6.58627	.16974	5.89151	22
39	.09893	10.1080	.11659	8.57718	.13432	7.44509	.15213	6.57339	.17004	5.88114	21
40	.09923	10.0780	.11688	8.55555	.13461	7.42871	.15243	6.56055	.17033	5.87080	20
41	.09952	10.0483	.11718	8.53402	.13491	7.41240	.15272	6.54777	.17063	5.86051	19
42	.09981	10.0187	.11747	8.51259	.13521	7.39616	.15302	6.53503	.17093	5.85024	18
43	.10011	9.98931	.11777	8.49128	.13550	7.37999	.15332	6.52234	.17123	5.84001	17
44	.10040	9.96007	.11806	8.47007	.13580	7.36389	.15362	6.50970	.17153	5.82982	16
45	.10069	9.93101	.11836	8.44896	.13609	7.34786	.15391	6.49710	.17183	5.81966	15
46	.10099	9.90211	.11865	8.42795	.13639	7.33190	.15421	6.48456	.17213	5.80953	14
47	.10128	9.87338	.11895	8.40705	.13669	7.31600	.15451	6.47206	.17243	5.79944	13
48	.10158	9.84482	.11924	8.38625	.13698	7.30018	.15481	6.45961	.17273	5.78938	12
49	.10187	9.81641	.11954	8.36555	.13728	7.28442	.15511	6.44720	.17303	5.77936	11
50	.10216	9.78817	.11983	8.34496	.13758	7.26873	.15540	6.43484	.17333	5.76937	10
51	.10246	9.76009	.12013	8.32446	.13787	7.25310	.15570	6.42253	.17363	5.75941	9
52	.10275	9.73217	.12042	8.30406	.13817	7.23754	.15600	6.41026	.17393	5.74949	8
53	.10305	9.70441	.12072	8.28376	.13846	7.22204	.15630	6.39804	.17423	5.73960	7
54	.10334	9.67680	.12101	8.26355	.13876	7.20661	.15660	6.38587	.17453	5.72974	6
55	.10363	9.64935	.12131	8.24345	.13906	7.19125	.15689	6.37374	.17483	5.71992	5
56	.10393	9.62205	.12160	8.22344	.13935	7.17594	.15719	6.36165	.17513	5.71013	4
57	.10422	9.59490	.12190	8.20352	.13965	7.16071	.15749	6.34961	.17543	5.70037	3
58	.10452	9.56791	.12219	8.18370	.13995	7.14553	.15779	6.33761	.17573	5.69064	2
59	.10481	9.54106	.12249	8.16398	.14024	7.13042	.15809	6.32566	.17603	5.68094	1
60	.10510	9.51436	.12278	8.14435	.14054	7.11537	.15838	6.31375	.17633	5.67128	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	84°		83°		82°		81°		80°		

′	10°		11°		12°		13°		14°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.17633	5.67128	.19438	5.14455	.21256	4.70463	.23087	4.33148	.24933	4.01078	60
1	.17663	5.66165	.19468	5.13658	.21286	4.69791	.23117	4.32573	.24964	4.00582	59
2	.17693	5.65205	.19498	5.12862	.21316	4.69121	.23148	4.32001	.24995	4.00086	58
3	.17723	5.64248	.19529	5.12069	.21347	4.68452	.23179	4.31430	.25026	3.99592	57
4	.17753	5.63295	.19559	5.11279	.21377	4.67786	.23209	4.30860	.25056	3.99099	56
5	.17783	5.62344	.19589	5.10490	.21408	4.67121	.23240	4.30291	.25087	3.98607	55
6	.17813	5.61397	.19619	5.09704	.21438	4.66458	.23271	4.29724	.25118	3.98117	54
7	.17843	5.60452	.19649	5.08921	.21469	4.65797	.23301	4.29159	.25149	3.97627	53
8	.17873	5.59511	.19680	5.08139	.21499	4.65138	.23332	4.28595	.25180	3.97139	52
9	.17903	5.58573	.19710	5.07360	.21529	4.64480	.23363	4.28032	.25211	3.96651	51
10	.17933	5.57638	.19740	5.06584	.21560	4.63825	.23393	4.27471	.25242	3.96165	50
11	.17963	5.56706	.19770	5.05809	.21590	4.63171	.23424	4.26911	.25273	3.95680	49
12	.17993	5.55777	.19801	5.05037	.21621	4.62518	.23455	4.26352	.25304	3.95196	48
13	.18023	5.54851	.19831	5.04267	.21651	4.61868	.23485	4.25795	.25335	3.94713	47
14	.18053	5.53927	.19861	5.03499	.21682	4.61219	.23516	4.25239	.25366	3.94232	46
15	.18083	5.53007	.19891	5.02734	.21712	4.60572	.23547	4.24685	.25397	3.93751	45
16	.18113	5.52090	.19921	5.01971	.21743	4.59927	.23578	4.24132	.25428	3.93271	44
17	.18143	5.51176	.19952	5.01210	.21773	4.59283	.23608	4.23580	.25459	3.92793	43
18	.18173	5.50264	.19982	5.00451	.21804	4.58641	.23639	4.23030	.25490	3.92316	42
19	.18203	5.49356	.20012	4.99695	.21834	4.58001	.23670	4.22481	.25521	3.91839	41
20	.18233	5.48451	.20042	4.98940	.21864	4.57363	.23700	4.21933	.25552	3.91364	40
21	.18263	5.47548	.20073	4.98188	.21895	4.56726	.23731	4.21387	.25583	3.90890	39
22	.18293	5.46648	.20103	4.97438	.21925	4.56091	.23762	4.20842	.25614	3.90417	38
23	.18323	5.45751	.20133	4.96690	.21956	4.55458	.23793	4.20298	.25645	3.89945	37
24	.18353	5.44857	.20164	4.95945	.21986	4.54826	.23823	4.19756	.25676	3.89474	36
25	.18384	5.43966	.20194	4.95201	.22017	4.54196	.23854	4.19215	.25707	3.89004	35
26	.18414	5.43077	.20224	4.94460	.22047	4.53568	.23885	4.18675	.25738	3.88536	34
27	.18444	5.42192	.20254	4.93721	.22078	4.52941	.23916	4.18137	.25769	3.88068	33
28	.18474	5.41309	.20285	4.92984	.22108	4.52316	.23946	4.17600	.25800	3.87601	32
29	.18504	5.40429	.20315	4.92249	.22139	4.51693	.23977	4.17064	.25831	3.87136	31
30	.18534	5.39552	.20345	4.91516	.22169	4.51071	.24008	4.16530	.25862	3.86671	30
31	.18564	5.38677	.20376	4.90785	.22200	4.50451	.24039	4.15997	.25893	3.86208	29
32	.18594	5.37805	.20406	4.90056	.22231	4.49832	.24069	4.15465	.25924	3.85745	28
33	.18624	5.36936	.20436	4.89330	.22261	4.49215	.24100	4.14934	.25955	3.85284	27
34	.18654	5.36070	.20466	4.88605	.22292	4.48600	.24131	4.14405	.25986	3.84824	26
35	.18684	5.35206	.20497	4.87882	.22322	4.47986	.24162	4.13877	.26017	3.84364	25
36	.18714	5.34345	.20527	4.87162	.22353	4.47374	.24193	4.13350	.26048	3.83906	24
37	.18745	5.33487	.20557	4.86444	.22383	4.46764	.24223	4.12825	.26079	3.83449	23
38	.18775	5.32631	.20588	4.85727	.22414	4.46155	.24254	4.12301	.26110	3.82992	22
39	.18805	5.31778	.20618	4.85013	.22444	4.45548	.24285	4.11778	.26141	3.82537	21
40	.18835	5.30928	.20648	4.84300	.22475	4.44942	.24316	4.11256	.26172	3.82083	20
41	.18865	5.30080	.20679	4.83590	.22505	4.44338	.24347	4.10736	.26203	3.81630	19
42	.18895	5.29235	.20709	4.82882	.22536	4.43735	.24377	4.10216	.26235	3.81177	18
43	.18925	5.28393	.20739	4.82175	.22567	4.43134	.24408	4.09699	.26266	3.80726	17
44	.18955	5.27553	.20770	4.81471	.22597	4.42534	.24439	4.09182	.26297	3.80276	16
45	.18986	5.26715	.20800	4.80769	.22628	4.41936	.24470	4.08666	.26328	3.79827	15
46	.19016	5.25880	.20830	4.80068	.22658	4.41340	.24501	4.08152	.26359	3.79378	14
47	.19046	5.25048	.20861	4.79370	.22689	4.40745	.24532	4.07639	.26390	3.78931	13
48	.19076	5.24218	.20891	4.78673	.22719	4.40152	.24562	4.07127	.26421	3.78485	12
49	.19106	5.23391	.20921	4.77978	.22750	4.39560	.24593	4.06616	.26452	3.78040	11
50	.19136	5.22566	.20952	4.77286	.22781	4.38969	.24624	4.06107	.26483	3.77595	10
51	.19166	5.21744	.20982	4.76595	.22811	4.38381	.24655	4.05599	.26515	3.77152	9
52	.19197	5.20925	.21013	4.75906	.22842	4.37793	.24686	4.05092	.26546	3.76709	8
53	.19227	5.20107	.21043	4.75219	.22872	4.37207	.24717	4.04586	.26577	3.76268	7
54	.19257	5.19293	.21073	4.74534	.22903	4.36623	.24747	4.04081	.26608	3.75828	6
55	.19287	5.18480	.21104	4.73851	.22934	4.36040	.24778	4.03578	.26639	3.75388	5
56	.19317	5.17671	.21134	4.73170	.22964	4.35459	.24809	4.03076	.26670	3.74950	4
57	.19347	5.16863	.21164	4.72490	.22995	4.34879	.24840	4.02574	.26701	3.74512	3
58	.19378	5.16058	.21195	4.71813	.23026	4.34300	.24871	4.02074	.26733	3.74075	2
59	.19408	5.15256	.21225	4.71137	.23056	4.33723	.24902	4.01576	.26764	3.73640	1
60	.19438	5.14455	.21256	4.70463	.23087	4.33148	.24933	4.01078	.26795	3.73205	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	79°		78°		77°		76°		75°		

′	15°		16°		17°		18°		19°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.26795	3.73205	.28675	3.48741	.30573	3.27085	.32492	3.07768	.34433	2.90421	60
1	.26826	3.72771	.28706	3.48359	.30605	3.26745	.32524	3.07464	.34465	2.90147	59
2	.26857	3.72338	.28738	3.47977	.30637	3.26406	.32556	3.07160	.34498	2.89873	58
3	.26888	3.71907	.28769	3.47596	.30669	3.26067	.32588	3.06857	.34530	2.89600	57
4	.26920	3.71476	.28800	3.47216	.30700	3.25729	.32621	3.06554	.34563	2.89327	56
5	.26951	3.71046	.28832	3.46837	.30732	3.25392	.32653	3.06252	.34596	2.89055	55
6	.26982	3.70616	.28864	3.46458	.30764	3.25055	.32685	3.05950	.34628	2.88783	54
7	.27013	3.70188	.28895	3.46080	.30796	3.24719	.32717	3.05649	.34661	2.88511	53
8	.27044	3.69761	.28927	3.45703	.30828	3.24383	.32749	3.05349	.34693	2.88240	52
9	.27076	3.69335	.28958	3.45327	.30860	3.24049	.32782	3.05049	.34726	2.87970	51
10	.27107	3.68909	.28990	3.44951	.30891	3.23714	.32814	3.04749	.34758	2.87700	50
11	.27138	3.68485	.29021	3.44576	.30923	3.23381	.32846	3.04450	.34791	2.87430	49
12	.27169	3.68061	.29053	3.44202	.30955	3.23048	.32878	3.04152	.34824	2.87161	48
13	.27201	3.67638	.29084	3.43829	.30987	3.22715	.32911	3.03854	.34856	2.86892	47
14	.27232	3.67217	.29116	3.43456	.31019	3.22384	.32943	3.03556	.34889	2.86624	46
15	.27263	3.66796	.29147	3.43084	.31051	3.22053	.32975	3.03260	.34922	2.86356	45
16	.27294	3.66376	.29179	3.42713	.31083	3.21722	.33007	3.02963	.34954	2.86089	44
17	.27326	3.65957	.29210	3.42343	.31115	3.21392	.33040	3.02667	.34987	2.85822	43
18	.27357	3.65538	.29242	3.41973	.31147	3.21063	.33072	3.02372	.35020	2.85555	42
19	.27388	3.65121	.29274	3.41604	.31178	3.20734	.33104	3.02077	.35052	2.85289	41
20	.27419	3.64705	.29305	3.41236	.31210	3.20406	.33136	3.01783	.35085	2.85023	40
21	.27451	3.64289	.29337	3.40869	.31242	3.20079	.33169	3.01489	.35118	2.84758	39
22	.27482	3.63874	.29368	3.40502	.31274	3.19752	.33201	3.01196	.35150	2.84494	38
23	.27513	3.63461	.29400	3.40136	.31306	3.19426	.33233	3.00903	.35183	2.84229	37
24	.27545	3.63048	.29432	3.39771	.31338	3.19100	.33266	3.00611	.35216	2.83965	36
25	.27576	3.62636	.29463	3.39406	.31370	3.18775	.33298	3.00319	.35248	2.83702	35
26	.27607	3.62224	.29495	3.39042	.31402	3.18451	.33330	3.00028	.35281	2.83439	34
27	.27638	3.61814	.29526	3.38679	.31434	3.18127	.33363	2.99738	.35314	2.83176	33
28	.27670	3.61405	.29558	3.38317	.31466	3.17804	.33395	2.99447	.35346	2.82914	32
29	.27701	3.60996	.29590	3.37955	.31498	3.17481	.33427	2.99158	.35379	2.82653	31
30	.27732	3.60588	.29621	3.37594	.31530	3.17159	.33460	2.98868	.35412	2.82391	30
31	.27764	3.60181	.29653	3.37234	.31562	3.16838	.33492	2.98580	.35445	2.82130	29
32	.27795	3.59775	.29685	3.36875	.31594	3.16517	.33524	2.98292	.35477	2.81870	28
33	.27826	3.59370	.29716	3.36516	.31626	3.16197	.33557	2.98004	.35510	2.81610	27
34	.27858	3.58966	.29748	3.36158	.31658	3.15877	.33589	2.97717	.35543	2.81350	26
35	.27889	3.58562	.29780	3.35800	.31690	3.15558	.33621	2.97430	.35576	2.81091	25
36	.27921	3.58160	.29811	3.35443	.31722	3.15240	.33654	2.97144	.35608	2.80833	24
37	.27952	3.57758	.29843	3.35087	.31754	3.14922	.33686	2.96858	.35641	2.80574	23
38	.27983	3.57357	.29875	3.34732	.31786	3.14605	.33718	2.96573	.35674	2.80316	22
39	.28015	3.56957	.29906	3.34377	.31818	3.14288	.33751	2.96288	.35707	2.80059	21
40	.28046	3.56557	.29938	3.34023	.31850	3.13972	.33783	2.96004	.35740	2.79802	20
41	.28077	3.56159	.29970	3.33670	.31882	3.13656	.33816	2.95721	.35772	2.79545	19
42	.28109	3.55761	.30001	3.33317	.31914	3.13341	.33848	2.95437	.35805	2.79289	18
43	.28140	3.55364	.30033	3.32965	.31946	3.13027	.33881	2.95155	.35838	2.79033	17
44	.28172	3.54968	.30065	3.32614	.31978	3.12713	.33913	2.94872	.35871	2.78778	16
45	.28203	3.54573	.30097	3.32264	.32010	3.12400	.33945	2.94591	.35904	2 78523	15
46	.28234	3.54179	.30128	3.31914	.32042	3.12087	.33978	2.94309	.35937	2.78269	14
47	.28266	3.53785	.30160	3.31565	.32074	3.11775	.34010	2.94028	.35969	2.78014	13
48	.28297	3.53393	.30192	3.31216	.32106	3.11464	.34043	2.93748	.36002	2.77761	12
49	.28329	3.53001	.30224	3.30868	.32139	3.11153	.34075	2.93468	.36035	2.77507	11
50	.28360	3.52609	.30255	3.30521	.32171	3.10842	.34108	2.93189	.36068	2.77254	10
51	.28391	3.52219	.30287	3.30174	.32203	3.10532	.34140	2.92910	.36101	2.77002	9
52	.28423	3.51829	.30319	3.29829	.32235	3.10223	.34173	2.92632	.36134	2.76750	8
53	.28454	3.51441	.30351	3.29483	.32267	3.09914	.34205	2.92354	.36167	2.76498	7
54	.28486	3.51053	.30382	3.29139	.32299	3.09606	.34238	2.92076	.36199	2.76247	6
55	.28517	3.50666	.30414	3.28795	.32331	3.09298	.34270	2.91799	.36232	2.75996	5
56	.28549	3.50279	.30446	3.28452	.32363	3.08991	.34303	2.91523	.36265	2.75746	4
57	.28580	3.49894	.30478	3.28109	.32396	3.08685	.34335	2.91246	.36298	2.75496	3
58	.28612	3.49509	.30509	3.27767	.32428	3.08379	.34368	2.90971	.36331	2.75246	2
59	.28643	3.49125	.30541	3.27426	.32460	3.08073	.34400	2.90696	.36364	2.74997	1
60	.28675	3.48741	.30573	3.27085	.32492	3.07768	.34433	2.90421	.36397	2.74748	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	74°		73°		72°		71°		70°		

′	20°		21°		22°		23°		24°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.36397	2.74748	.38386	2.60509	.40403	2.47509	.42447	2.35585	.44523	2.24604	60
1	.36430	2.74490	.38420	2.60283	.40436	2.47302	.42482	2.35395	.44558	2.24428	59
2	.36463	2.74251	.38453	2.60057	.40470	2.47095	.42516	2.35205	.44593	2.24252	58
3	.36496	2.74004	.38487	2.59831	.40504	2.46888	.42551	2.35015	.44627	2.24077	57
4	.36529	2.73756	.38520	2.59606	.40538	2.46682	.42585	2.34825	.44662	2.23902	56
5	.36562	2.73509	.38553	2.59381	.40572	2.46476	.42619	2.34636	.44697	2.23727	55
6	.36595	2.73263	.38587	2.59156	.40606	2.46270	.42654	2.34447	.44732	2.23553	54
7	.36628	2.73017	.38620	2.58932	.40640	2.46065	.42688	2.34258	.44767	2.23378	53
8	.36661	2.72771	.38654	2.58708	.40674	2.45860	.42722	2.34069	.44802	2.23204	52
9	.36694	2.72526	.38687	2.58484	.40707	2.45655	.42757	2.33881	.44837	2.23030	51
10	.36727	2.72281	.38721	2.58261	.40741	2.45451	.42791	2.33693	.44872	2.22857	50
11	.36760	2.72036	.38754	2.58038	.40775	2.45246	.42826	2.33505	.44907	2 22683	49
12	.36793	2.71792	.38787	2.57815	.40809	2.45043	.42860	2.33317	.44942	2.22510	48
13	.36826	2.71548	.38821	2.57593	.40843	2.44839	.42894	2.33130	.44977	2.22337	47
14	.36859	2.71305	.38854	2.57371	.40877	2.44636	.42929	2.32943	.45012	2.22164	46
15	.36892	2.71062	.38888	2.57150	.40911	2.44433	.42963	2.32756	.45047	2.21992	45
16	.36925	2.70819	.38921	2.56928	.40945	2.44230	.42998	2.32570	.45082	2.21819	44
17	.36958	2.70577	.38955	2.56707	.40979	2.44027	.43032	2.32383	.45117	2.21647	43
18	.36991	2.70335	.38988	2.56487	.41013	2.43825	.43067	2.32197	.45152	2.21475	42
19	.37024	2.70094	.39022	2.56266	.41047	2.43623	.43101	2.32012	.45187	2.21304	41
20	.37057	2.69853	.39055	2.56046	.41081	2.43422	.43136	2.31826	.45222	2.21132	40
21	.37090	2.69612	.39089	2.55827	.41115	2.43220	.43170	2.31641	.45257	2.20961	39
22	.37123	2.69371	.39122	2.55608	.41149	2.43019	.43205	2.31456	.45292	2.20790	38
23	.37157	2.69131	.39156	2.55389	.41183	2.42819	.43230	2.31271	.45327	2.20619	37
24	.37190	2.68892	.39190	2.55170	.41217	2.42618	.43274	2.31086	.45362	2.20449	36
25	.37223	2.68653	.39223	2.54952	.41251	2.42418	.43308	2.30902	.45397	2.20278	35
26	.37256	2.68414	.39257	2.54734	.41285	2.42218	.43343	2.30718	.45432	2.20108	34
27	.37289	2.68175	.39290	2.54516	.41319	2.42019	.43378	2.30534	.45467	2.19938	33
28	.37322	2.67937	.39324	2.54299	.41353	2.41819	.43412	2.30351	.45502	2.19769	32
29	.37355	2.67700	.39357	2.54082	.41387	2.41620	.43447	2.30167	.45538	2.19599	31
30	.37388	2.67462	.39391	2.53865	.41421	2.41421	.43481	2.29984	.45573	2.19430	30
31	.37422	2.67225	.39425	2.53648	.41455	2.41223	.43516	2.29801	.45608	2.19261	29
32	.37455	2.66989	.39458	2.53432	.41490	2.41025	.43550	2.29619	.45643	2.19092	28
33	.37488	2.66752	.39492	2.53217	.41524	2.40827	.43585	2.29437	.45678	2.18923	27
34	.37521	2.66516	.39526	2.53001	.41558	2.40629	.43620	2.29254	.45713	2.18755	26
35	.37554	2.66281	.39559	2.52786	.41592	2.40432	.43654	2.29073	.45748	2.18587	25
36	.37588	2.66046	.39593	2.52571	.41626	2.40235	.43689	2.28891	.45784	2.18419	24
37	.37621	2.65811	.39626	2.52357	.41660	2.40038	.43724	2.28710	.45819	2.18251	23
38	.37654	2.65576	.39660	2.52142	.41694	2.39841	.43758	2.28528	.45854	2.18084	22
39	.37687	2.65342	.39694	2.51929	.41728	2.39645	.43793	2.28348	.45889	2.17916	21
40	.37720	2.65109	.39727	2.51715	.41763	2.39449	.43828	2.28167	.45924	2.17749	20
41	.37754	2.64875	.39761	2.51502	.41797	2.39253	.43862	2.27987	.45960	2.17582	19
42	.37787	2.64642	.39795	2.51289	.41831	2.39058	.43897	2.27806	.45995	2.17416	18
43	.37820	2.64410	.39829	2.51076	.41865	2.38863	.43932	2.27626	.46030	2.17249	17
44	.37853	2.64177	.39862	2.50864	.41899	2.38668	.43966	2.27447	.46065	2.17083	16
45	.37887	2.63945	.39896	2.50652	.41933	2.38473	.44001	2.27267	.46101	2.16917	15
46	.37920	2.63714	.39930	2.50440	.41968	2.38279	.44036	2.27088	.46136	2.16751	14
47	.37953	2.63483	.39963	2.50229	.42002	2.38084	.44071	2.26909	.46171	2.16585	13
48	.37986	2.63252	.39997	2.50018	.42036	2.37891	.44105	2.26730	.46206	2.16420	12
49	.38020	2.63021	.40031	2.49807	.42070	2.37697	.44140	2.26552	.46242	2.16255	11
50	.38053	2.62791	.40065	2.49597	.42105	2.37504	.44175	2 26374	.46277	2.16090	10
51	.38086	2.62561	.40098	2.49386	42139	2.37311	.44210	2.26196	.46312	2.15925	9
52	.38120	2.62332	.40132	2.49177	.42173	2.37118	.44244	2.26018	.46346	2.15760	8
53	.38153	2.62103	.40166	2.48967	.42207	2.36925	.44279	2.25840	.46383	2.15596	7
54	.38186	2.61874	.40200	2.48758	.42242	2.36733	.44314	2.25663	.46418	2.15432	6
55	.38220	2.61646	.40234	2.48549	.42276	2.36541	.44349	2.25486	.46454	2.15268	5
56	.38253	2.61418	.40267	2.48340	.42310	2.36349	.44384	2.25309	.46489	2.15104	4
57	.38286	2.61190	.40301	2.48132	.42345	2.36158	.44418	2.25132	.46525	2.14940	3
58	.38320	2.60963	.40335	2.47924	.42379	2.35967	.44453	2.24956	.46560	2.14777	2
59	.38353	2.60736	.40369	2.47716	.42413	2.35776	.44488	2.24780	.46595	2.14614	1
60	.38386	2.60509	.40403	2.47509	.42447	2.35585	.44523	2.24604	.46631	2.14451	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	69°		68°		67°		66°		65°		

′	25°		26°		27°		28°		29°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.46631	2.14451	.48773	2.05030	.50953	1.96261	.53171	1.88073	.55431	1.80405	60
1	.46666	2.14288	.48809	2.04879	.50989	1.96120	.53208	1.87941	.55469	1.80281	59
2	.46702	2.14125	.48845	2.04728	.51026	1.95979	.53246	1.87809	.55507	1.80158	58
3	.46737	2.13963	.48881	2.04577	.51063	1.95838	.53283	1.87677	.55545	1.80034	57
4	.46772	2.13801	.48917	2.04426	.51099	1.95698	.53320	1.87546	.55583	1.79911	56
5	.46808	2.13639	.48953	2.04276	.51136	1.95557	.53358	1.87415	.55621	1.79788	55
6	.46843	2.13477	.48989	2.04125	.51173	1.95417	.53395	1.87283	.55659	1.79665	54
7	.46879	2.13316	.49026	2.03975	.51209	1.95277	.53432	1.87152	.55697	1.79542	53
8	.46914	2.13154	.49062	2.03825	.51246	1.95137	.53470	1.87021	.55736	1.79419	52
9	.46950	2.12993	.49098	2.03675	.51283	1.94997	.53507	1.86891	.55774	1.79296	51
10	.46985	2.12832	.49134	2.03526	.51319	1.94858	.53545	1.86760	.55812	1.79174	50
11	.47021	2.12671	.49170	2.03376	.51356	1.94718	.53582	1.86630	.55850	1.79051	49
12	.47056	2.12511	.49206	2.03227	.51393	1.94579	.53620	1.86499	.55888	1.78929	48
13	.47092	2.12350	.49242	2.03078	.51430	1.94440	.53657	1.86369	.55926	1.78807	47
14	.47128	2.12190	.49278	2.02929	.51467	1.94301	.53694	1.86239	.55964	1.78685	46
15	.47163	2.12030	.49315	2.02780	.51503	1.94162	.53732	1.86109	.56003	1.78563	45
16	.47199	2.11871	.49351	2.02631	.51540	1.94023	.53769	1.85979	.56041	1.78441	44
17	.47234	2.11711	.49387	2.02483	.51577	1.93885	.53807	1.85850	.56079	1.78319	43
18	.47270	2.11552	.49423	2.02335	.51614	1.93746	.53844	1.85720	.56117	1.78198	42
19	.47305	2.11392	.49459	2.02187	.51651	1.93608	.53882	1.85591	.56156	1.78077	41
20	.47341	2.11233	.49495	2.02039	.51688	1.93470	.53920	1.85462	.56194	1.77955	40
21	.47377	2.11075	.49532	2.01891	.51724	1.93332	.53957	1.85333	.56232	1.77834	39
22	.47412	2.10916	.49568	2.01743	.51761	1.93195	.53995	1.85204	.56270	1.77713	38
23	.47448	2.10758	.49604	2.01596	.51798	1.93057	.54032	1.85075	.56309	1.77592	37
24	.47483	2.10600	.49640	2.01449	.51835	1.92920	.54070	1.84946	.56347	1.77471	36
25	.47519	2.10442	.49677	2.01302	.51872	1.92782	.54107	1.84818	.56385	1.77351	35
26	.47555	2.10284	.49713	2.01155	.51909	1.92645	.54145	1.84689	.56424	1.77230	34
27	.47590	2.10126	.49749	2.01008	.51946	1.92508	.54183	1.84561	.56462	1.77110	33
28	.47626	2.09969	.49786	2.00862	.51983	1.92371	.54220	1.84433	.56501	1.76990	32
29	.47662	2.09811	.49822	2.00715	.52020	1.92235	.54258	1.84305	.56539	1.76869	31
30	.47698	2.09654	.49858	2.00569	.52057	1.92098	.54296	1.84177	.56577	1.76749	30
31	.47733	2.09498	.49894	2.00423	.52094	1.91962	.54333	1.84049	.56616	1.76629	29
32	.47769	2.09341	.49931	2.00277	.52131	1.91826	.54371	1.83922	.56654	1.76510	28
33	.47805	2.09184	.49967	2.00131	.52168	1.91690	.54409	1.83794	.56693	1.76390	27
34	.47840	2.09028	.50004	1.99986	.52205	1.91554	.54446	1.83667	.56731	1.76271	26
35	.47876	2.08872	.50040	1.99841	.52242	1.91418	.54484	1.83540	.56769	1.76151	25
36	.47912	2.08716	.50076	1.99695	.52279	1.91282	.54522	1.83413	.56808	1.76032	24
37	.47948	2.08560	.50113	1.99550	.52316	1.91147	.54560	1.83286	.56846	1.75913	23
38	.47984	2.08405	.50149	1.99406	.52353	1.91012	.54597	1.83159	.56885	1.75794	22
39	.48019	2.08250	.50185	1.99261	.52390	1.90876	.54635	1.83033	.56923	1.75675	21
40	.48055	2.08094	.50222	1.99116	.52427	1.90741	.54673	1.82906	.56962	1.75556	20
41	.48091	2.07939	.50258	1.98972	.52464	1.90607	.54711	1.82780	.57000	1.75437	19
42	.48127	2.07785	.50295	1.98828	.52501	1.90472	.54748	1.82654	.57039	1.75319	18
43	.48163	2.07630	.50331	1.98684	.52538	1.90337	.54786	1.82528	.57078	1.75200	17
44	.48198	2.07476	.50368	1.98540	.52575	1.90203	.54824	1.82402	.57116	1.75082	16
45	.48234	2.07321	.50404	1.98396	.52613	1.90069	.54862	1.82276	.57155	1.74964	15
46	.48270	2.07167	.50441	1.98253	.52650	1.89935	.54900	1.82150	.57193	1.74846	14
47	.48306	2.07014	.50477	1.98110	.52687	1.89801	.54938	1.82025	.57232	1.74728	13
48	.48342	2.06860	.50514	1.97966	.52724	1.89667	.54975	1.81899	.57271	1.74610	12
49	.48378	2.06706	.50550	1.97823	.52761	1.89533	.55013	1.81774	.57309	1.74492	11
50	.48414	2.06553	.50587	1.97681	.52798	1.89400	.55051	1.81649	.57348	1.74375	10
51	.48450	2.06400	.50623	1.97538	.52836	1.89266	.55089	1.81524	.57386	1.74257	9
52	.48486	2.06247	.50660	1.97395	.52873	1.89133	.55127	1.81399	.57425	1.74140	8
53	.48521	2.06094	.50696	1.97253	.52910	1.89000	.55165	1.81274	.57464	1.74022	7
54	.48557	2.05942	.50733	1.97111	.52947	1.88867	.55203	1.81150	.57503	1.73905	6
55	.48593	2.05790	.50769	1.96969	.52985	1.88734	.55241	1.81025	.57541	1.73788	5
56	.48629	2.05637	.50806	1.96827	.53022	1.88602	.55279	1.80901	.57580	1.73671	4
57	.48665	2.05485	.50843	1.96685	.53059	1.88469	.55317	1.80777	.57619	1.73555	3
58	.48701	2.05333	.50879	1.96544	.53096	1.88337	.55355	1.80653	.57657	1.73438	2
59	.48737	2.05182	.50916	1.96402	.53134	1.88205	.55393	1.80529	.57696	1.73321	1
60	.48773	2.05030	.50953	1.96261	.53171	1.88073	.55431	1.80405	.57735	1.73205	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	64°		63°		62°		61°		60°		

′	30°		31°		32°		33°		34°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.57735	1.73205	.60086	1.66428	.62487	1.60033	.64941	1.53986	.67451	1.48256	60
1	.57774	1.73089	.60126	1.66318	.62527	1.59930	.64982	1.53888	.67493	1.48163	59
2	.57813	1.72973	.60165	1.66209	.62568	1.59826	.65024	1.53791	.67536	1.48070	58
3	.57851	1.72857	.60205	1.66099	.62608	1.59723	.65065	1.53693	.67578	1.47977	57
4	.57890	1.72741	.60245	1.65990	.62649	1.59620	.65106	1.53595	.67620	1.47885	56
5	.57929	1.72625	.60284	1.65881	.62689	1.59517	.65148	1.53497	.67663	1.47792	55
6	.57968	1.72509	.60324	1.65772	.62730	1.59414	.65189	1.53400	.67705	1.47699	54
7	.58007	1.72393	.60364	1.65663	.62770	1.59311	.65231	1.53302	.67748	1.47607	53
8	.58046	1.72278	.60403	1.65554	.62811	1.59208	.65272	1.53205	.67790	1.47514	52
9	.58085	1.72163	.60443	1.65445	.62852	1.59105	.65314	1.53107	.67832	1.47422	51
10	.58124	1.72047	.60483	1.65337	.62892	1.59002	.65355	1.53010	.67875	1.47330	50
11	.58162	1.71932	.60522	1.65228	.62933	1.58900	.65397	1.52913	.67917	1.47238	49
12	.58201	1.71817	.60562	1.65120	.62973	1.58797	.65438	1.52816	.67960	1.47146	48
13	.58240	1.71702	.60602	1.65011	.63014	1.58695	.65480	1.52719	.68002	1.47053	47
14	.58279	1.71588	.60642	1.64903	.63055	1.58593	.65521	1.52622	.68045	1.46962	46
15	.58318	1.71473	.60681	1.64795	.63095	1.58490	.65563	1.52525	.68088	1.46870	45
16	.58357	1.71358	.60721	1.64687	.63136	1.58388	.65604	1.52429	.68130	1.46778	44
17	.58396	1.71244	.60761	1.64579	.63177	1.58286	.65646	1.52332	.68173	1.46686	43
18	.58435	1.71129	.60801	1.64471	.63217	1.58184	.65688	1.52235	.68215	1.46595	42
19	.58474	1.71015	.60841	1.64363	.63258	1.58083	.65729	1.52139	.68258	1.46503	41
20	.58513	1.70901	.60881	1.64256	.63299	1.57981	.65771	1.52043	.68301	1.46411	40
21	.58552	1.70787	.60921	1.64148	.63340	1.57879	.65813	1.51946	.68343	1.46320	39
22	.58591	1.70673	.60960	1.64041	.63380	1.57778	.65854	1.51850	.68386	1.46229	38
23	.58631	1.70560	.61000	1.63934	.63421	1.57676	.65896	1.51754	.68429	1.46137	37
24	.58670	1.70446	.61040	1.63826	.63462	1.57575	.65938	1.51658	.68471	1.46046	36
25	.58709	1.70332	.61080	1.63719	.63503	1.57474	.65980	1.51562	.68514	1.45955	35
26	.58748	1.70219	.61120	1.63612	.63544	1.57372	.66021	1.51466	.68557	1.45864	34
27	.58787	1.70106	.61160	1.63505	.63584	1.57271	.66063	1.51370	.68600	1.45773	33
28	.58826	1.69992	.61200	1.63398	.63625	1.57170	.66105	1.51275	.68642	1.45682	32
29	.58865	1.69879	.61240	1.63292	.63666	1.57069	.66147	1.51179	.68685	1.45592	31
30	.58905	1.69766	.61280	1.63185	.63707	1.56969	.66189	1.51084	.68728	1.45501	30
31	.58944	1.69653	.61320	1.63079	.63748	1.56868	.66230	1.50988	.68771	1.45410	29
32	.58983	1.69541	.61360	1.62972	.63789	1.56767	.66272	1.50893	.68814	1.45320	28
33	.59022	1.69428	.61400	1.62866	.63830	1.56667	.66314	1.50797	.68857	1.45229	27
34	.59061	1.69316	.61440	1.62760	.63871	1.56566	.66356	1.50702	.68900	1.45139	26
35	.59101	1.69203	.61480	1.62654	.63912	1.56466	.66398	1.50607	.68942	1.45049	25
36	.59149	1.69091	.61520	1.62548	.63953	1.56366	.66440	1.50512	.68985	1.44958	24
37	.59179	1.68979	.61561	1.62442	.63994	1.56265	.66482	1.50417	.69028	1.44868	23
38	.59218	1.68866	.61601	1.62336	.64035	1.56165	.66524	1.50322	.69071	1.44778	22
39	.59258	1.68754	.61641	1.62230	.64076	1.56065	.66566	1.50228	.69114	1.44688	21
40	.59297	1.68643	.61681	1.62125	.64117	1.55966	.66608	1.50133	.69157	1.44598	20
41	.59336	1.68531	.61721	1.62019	.64158	1.55866	.66650	1.50038	.69200	1.44508	19
42	.59376	1.68419	.61761	1.61914	.64199	1.55766	.66692	1.49944	.69243	1.44418	18
43	.59415	1.68308	.61801	1.61808	.64240	1.55666	.66734	1.49849	.69286	1.44329	17
44	.59454	1.68196	.61842	1.61703	.64281	1.55567	.66776	1.49755	.69329	1.44239	16
45	.59494	1.68085	.61882	1.61598	.64322	1.55467	.66818	1.49661	.69372	1.44149	15
46	.59533	1.67974	.61922	1.61493	.64363	1.55368	.66860	1.49566	.69416	1.44060	14
47	.59573	1.67863	.61962	1.61388	.64404	1.55269	.66902	1.49472	.69459	1.43970	13
48	.59612	1.67752	.62003	1.61283	.64446	1.55170	.66944	1.49378	.69502	1.43881	12
49	.59651	1.67641	.62043	1.61179	.64487	1.55071	.66986	1.49284	.69545	1.43792	11
50	.59691	1.67530	.62083	1.61074	.64528	1.54972	.67028	1.49190	.69588	1.43703	10
51	.59730	1.67419	.62124	1.60970	.64569	1.54873	.67071	1.49097	.69631	1.43614	9
52	.59770	1.67309	.62164	1.60865	.64610	1.54774	.67113	1.49003	.69675	1.43525	8
53	.59809	1.67198	.62204	1.60761	.64652	1.54675	.67155	1.48909	.69718	1.43436	7
54	.59849	1.67088	.62245	1.60657	.64693	1.54576	.67197	1.48816	.69761	1.43347	6
55	.59888	1.66978	.62285	1.60553	.64734	1.54478	.67239	1.48722	.69804	1.43258	5
56	.59928	1.66867	.62325	1.60449	.64775	1.54379	.67282	1.48629	.69847	1.43169	4
57	.59967	1.66757	.62366	1.60345	.64817	1.54281	.67324	1.48536	.69891	1.43080	3
58	.60007	1.66647	.62406	1.60241	.64858	1.54183	.67366	1.48442	.69934	1.42992	2
59	.60046	1.66538	.62446	1.60137	.64899	1.54085	.67409	1.48349	.69977	1.42903	1
60	.60086	1.66428	.62487	1.60033	.64941	1.53986	.67451	1.48256	.70021	1.42815	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	59°		58°		57°		56°		55°		

′	35°		36°		37°		38°		39°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.70021	1.42815	.72654	1.37638	.75355	1.32704	.78129	1.27994	.80978	1.23490	60
1	.70064	1.42726	.72699	1.37554	.75401	1.32624	.78175	1.27917	.81027	1.23416	59
2	.70107	1.42638	.72743	1.37470	.75447	1.32544	.78222	1.27841	.81075	1.23343	58
3	.70151	1.42550	.72788	1.37386	.75492	1.32464	.78269	1.27764	.81123	1.23270	57
4	.70194	1.42462	.72832	1.37302	.75538	1.32384	.78316	1.27688	.81171	1.23196	56
5	.70238	1.42374	.72877	1.37218	.75584	1.32304	.78363	1.27611	.81220	1.23123	55
6	.70281	1.42286	.72921	1.37134	.75629	1.32224	.78410	1.27535	.81268	1.23050	54
7	.70325	1.42198	.72966	1.37050	.75675	1.32144	.78457	1.27458	.81316	1.22977	53
8	.70368	1.42110	.73010	1.36967	.75721	1.32064	.78504	1.27382	.81364	1.22904	52
9	.70412	1.42022	.73055	1.36883	.75767	1.31984	.78551	1.27306	.81413	1.22831	51
10	.70455	1.41934	.73100	1.36800	.75812	1.31904	.78598	1.27230	.81461	1.22758	50
11	.70499	1.41847	.73144	1.36716	.75858	1.31825	.78645	1.27153	.81510	1.22685	49
12	.70542	1.41759	.73189	1.36633	.75904	1.31745	.78692	1.27077	.81558	1.22612	48
13	.70586	1.41672	.73234	1.36549	.75950	1.31666	.78739	1.27001	.81606	1.22539	47
14	.70629	1.41584	.73278	1.36466	.75996	1.31586	.78786	1.26925	.81655	1.22467	46
15	.70673	1.41497	.73323	1.36383	.76042	1.31507	.78834	1.26849	.81703	1.22394	45
16	.70717	1.41409	.73368	1.36300	.76088	1.31427	.78881	1.26774	.81752	1.22321	44
17	.70760	1.41322	.73413	1.36217	.76134	1.31348	.78928	1.26698	.81800	1.22249	43
18	.70804	1.41235	.73457	1.36134	.76180	1.31269	.78975	1.26622	.81849	1.22176	42
19	.70848	1.41148	.73502	1.36051	.76226	1.31190	.79022	1.26546	.81898	1.22104	41
20	.70891	1.41061	.73547	1.35968	.76272	1.31110	.79070	1.26471	.81946	1.22031	40
21	.70935	1.40974	.73592	1.35885	.76318	1.31031	.79117	1.26395	.81995	1.21959	39
22	.70979	1.40887	.73637	1.35802	.76364	1.30952	.79164	1.26319	.82044	1.21886	38
23	.71023	1.40800	.73681	1.35719	.76410	1.30873	.79212	1.26244	.82092	1.21814	37
24	.71066	1.40714	.73726	1.35637	.76456	1.30795	.79259	1.26169	.82141	1.21742	36
25	.71110	1.40627	.73771	1.35554	.76502	1.30716	.79306	1.26093	.82190	1.21670	35
26	.71154	1.40540	.73816	1.35472	.76548	1.30637	.79354	1.26018	.82238	1.21598	34
27	.71198	1.40454	.73861	1.35389	.76594	1.30558	.79401	1.25943	.82287	1.21526	33
28	.71242	1.40367	.73906	1.35307	.76640	1.30480	.79449	1.25867	.82336	1.21454	32
29	.71285	1.40281	.73951	1.35224	.76686	1.30401	.79496	1.25792	.82385	1.21382	31
30	.71329	1.40195	.73996	1.35142	.76733	1.30323	.79544	1.25717	.82434	1.21310	30
31	.71373	1.40109	.74041	1.35060	.76779	1.30244	.79591	1.25642	.82483	1.21238	29
32	.71417	1.40022	.74086	1.34978	.76825	1.30166	.79639	1.25567	.82531	1.21166	28
33	.71461	1.39936	.74131	1.34896	.76871	1.30087	.79686	1.25492	.82580	1.21094	27
34	.71505	1.39850	.74176	1.34814	.76918	1.30009	.79734	1.25417	.82629	1.21023	26
35	.71549	1.39764	.74221	1.34732	.76964	1.29931	.79781	1.25343	.82678	1.20951	25
36	.71593	1.39679	.74267	1.34650	.77010	1.29853	.79829	1.25268	.82727	1.20879	24
37	.71637	1.39593	.74312	1.34568	.77057	1.29775	.79877	1.25193	.82776	1.20808	23
38	.71681	1.39507	.74357	1.34487	.77103	1.29696	.79924	1.25118	.82825	1.20736	22
39	.71725	1.39421	.74402	1.34405	.77149	1.29618	.79972	1.25044	.82874	1.20665	21
40	.71769	1.39336	.74447	1.34323	.77196	1.29541	.80020	1.24969	.82923	1.20593	20
41	.71813	1.39250	.74492	1.34242	.77242	1.29463	.80067	1.24895	.82972	1.20522	19
42	.71857	1.39165	.74538	1.34160	.77289	1.29385	.80115	1.24820	.83022	1.20451	18
43	.71901	1.39079	.74583	1.34079	.77335	1.29307	.80163	1.24746	.83071	1.20379	17
44	.71946	1.38994	.74628	1.33998	.77382	1.29229	.80211	1.24672	.83120	1.20308	16
45	.71990	1.38909	.74674	1.33916	.77428	1.29152	.80258	1.24597	.83169	1.20237	15
46	.72034	1.38824	.74719	1.33835	.77475	1.29074	.80306	1.24523	.83218	1.20166	14
47	.72078	1.38738	.74764	1.33754	.77521	1.28997	.80354	1.24449	.83268	1.20095	13
48	.72122	1.38653	.74810	1.33673	.77568	1.28919	.80402	1.24375	.83317	1.20024	12
49	.72167	1.38568	.74855	1.33592	.77615	1.28842	.80450	1.24301	.83366	1.19953	11
50	.72211	1.38484	.74900	1.33511	.77661	1.28764	.80498	1.24227	.83415	1.19882	10
51	.72255	1.38399	.74946	1.33430	.77708	1.28687	.80546	1.24153	.83465	1.19811	9
52	.72299	1.38314	.74991	1.33349	.77754	1.28610	.80594	1.24079	.83514	1.19740	8
53	.72344	1.38229	.75037	1.33268	.77801	1.28533	.80642	1.24005	.83564	1.19669	7
54	.72388	1.38145	.75082	1.33187	.77848	1.28456	.80690	1.23931	.83613	1.19599	6
55	.72432	1.38060	.75128	1.33107	.77895	1.28379	.80738	1.23858	.83662	1.19528	5
56	.72477	1.37976	.75173	1.33026	.77941	1.28302	.80786	1.23784	.83712	1.19457	4
57	.72521	1.37891	.75219	1.32946	.77988	1.28225	.80834	1.23710	.83761	1.19387	3
58	.72565	1.37807	.75264	1.32865	.78035	1.28148	.80882	1.23637	.83811	1.19316	2
59	.72610	1.37722	.75310	1.32785	.78082	1.28071	.80930	1.23563	.83860	1.19246	1
60	.72654	1.37638	.75355	1.32704	.78129	1.27994	.80978	1.23490	.83910	1.19175	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	54°		53°		52°		51°		50°		

′	40°		41°		42°		43°		44°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.83910	1.19175	.86929	1.15037	.90040	1.11061	.93252	1.07237	.96569	1.03553	60
1	.83960	1.19105	.86980	1.14969	.90093	1.10996	.93306	1.07174	.96625	1.03493	59
2	.84009	1.19035	.87031	1.14902	.90146	1.10931	.93360	1.07112	.96681	1.03433	58
3	.84059	1.18964	.87082	1.14834	.90199	1.10867	.93415	1.07049	.96738	1.03372	57
4	.84108	1.18894	.87133	1.14767	.90251	1.10802	.93469	1.06987	.96794	1.03312	56
5	.84158	1.18824	.87184	1.14699	.90304	1.10737	.93524	1.06925	.96850	1.03252	55
6	.84208	1.18754	.87236	1.14632	.90357	1.10672	.93578	1.06862	.96907	1.03192	54
7	.84258	1.18684	.87287	1.14565	.90410	1.10607	.93633	1.06800	.96963	1.03132	53
8	.84307	1.18614	.87338	1.14498	.90463	1.10543	.93688	1.06738	.97020	1.03072	52
9	.84357	1.18544	.87389	1.14430	.90516	1.10478	.93742	1.06676	.97076	1.03012	51
10	.84407	1.18474	.87441	1.14363	.90569	1.10414	.93797	1.06613	.97133	1.02952	50
11	.84457	1.18404	.87492	1.14296	.90621	1.10349	.93852	1.06551	.97189	1.02892	49
12	.84507	1.18334	.87543	1.14229	.90674	1.10285	.93906	1.06489	.97246	1.02832	48
13	.84556	1.18264	.87595	1.14162	.90727	1.10220	.93961	1.06427	.97302	1.02772	47
14	.84606	1.18194	.87646	1.14095	.90781	1.10156	.94016	1.06365	.97359	1.02713	46
15	.84656	1.18125	.87698	1.14028	.90834	1.10091	.94071	1.06303	.97416	1.02653	45
16	.84706	1.18055	.87749	1.13961	.90887	1.10027	.94125	1.06241	.97472	1.02593	44
17	.84756	1.17986	.87801	1.13894	.90940	1.09963	.94180	1.06179	.97529	1.02533	43
18	.84806	1.17916	.87852	1.13828	.90993	1.09899	.94235	1.06117	.97586	1.02474	42
19	.84856	1.17846	.87904	1.13761	.91046	1.09834	.94290	1.06056	.97643	1.02414	41
20	.84906	1.17777	.87955	1.13694	.91099	1.09770	.94345	1.05994	.97700	1.02355	40
21	.84956	1.17708	.88007	1.13627	.91153	1.09706	.94400	1.05932	.97756	1.02295	39
22	.85006	1.17638	.88059	1.13561	.91206	1.09642	.94455	1.05870	.97813	1.02236	38
23	.85057	1.17569	.88110	1.13494	.91259	1.09578	.94510	1.05809	.97870	1.02176	37
24	.85107	1.17500	.88162	1.13428	.91313	1.09514	.94565	1.05747	.97927	1.02117	36
25	.85157	1.17430	.88214	1.13361	.91366	1.09450	.94620	1.05685	.97984	1.02057	35
26	.85207	1.17361	.88265	1.13295	.91419	1.09386	.94676	1.05624	.98041	1.01998	34
27	.85257	1.17292	.88317	1.13228	.91473	1.09322	.94731	1.05562	.98098	1.01939	33
28	.85308	1.17223	.88369	1.13162	.91526	1.09258	.94786	1.05501	.98155	1.01879	32
29	.85358	1.17154	.88421	1.13096	.91580	1.09195	.94841	1.05439	.98213	1.01820	31
30	.85408	1.17085	.88473	1.13029	.91633	1.09131	.94896	1.05378	.98270	1.01761	30
31	.85458	1.17016	.88524	1.12963	.91687	1.09067	.94952	1.05317	.98327	1.01702	29
32	.85509	1.16947	.88576	1.12897	.91740	1.09003	.95007	1.05255	.98384	1.01642	28
33	.85559	1.16878	.88628	1.12831	.91794	1.08940	.95062	1.05194	.98441	1.01583	27
34	.85609	1.16809	.88680	1.12765	.91847	1.08876	.95118	1.05133	.98499	1.01524	26
35	.85660	1.16741	.88732	1.12699	.91901	1.08813	.95173	1.05072	.98556	1.01465	25
36	.85710	1.16672	.88784	1.12633	.91955	1.08749	.95229	1.05010	.98613	1.01406	24
37	.85761	1.16603	.88836	1.12567	.92008	1.08686	.95284	1.04949	.98671	1.01347	23
38	.85811	1.16535	.88888	1.12501	.92062	1.08622	.95340	1.04888	.98728	1.01288	22
39	.85862	1.16466	.88940	1.12435	.92116	1.08559	.95395	1.04827	.98786	1.01229	21
40	.85912	1.16398	.88992	1.12369	.92170	1.08496	.95451	1.04766	.98843	1.01170	20
41	.85963	1.16329	.89045	1.12303	.92224	1.08432	.95506	1.04705	.98901	1.01112	19
42	.86014	1.16261	.89097	1.12238	.92277	1.08369	.95562	1.04644	.98958	1.01053	18
43	.86064	1.16192	.89149	1.12172	.92331	1.08306	.95618	1.04583	.99016	1.00994	17
44	.86115	1.16124	.89201	1.12106	.92385	1.08243	.95673	1.04522	.99073	1.00935	16
45	.86166	1.16056	.89253	1.12041	.92439	1.08179	.95729	1.04461	.99131	1.00876	15
46	.86216	1.15987	.89306	1.11975	.92493	1.08116	.95785	1.04401	.99189	1.00818	14
47	.86267	1.15919	.89358	1.11909	.92547	1.08053	.95841	1.04340	.99247	1.00759	13
48	.86318	1.15851	.89410	1.11844	.92601	1.07990	.95897	1.04279	.99304	1.00701	12
49	.86368	1.15783	.89463	1.11778	.92655	1.07927	.95952	1.04218	.99362	1.00642	11
50	.86419	1.15715	.89515	1.11713	.92709	1.07864	.96008	1.04158	.99420	1.00583	10
51	.86470	1.15647	.89567	1.11648	.92763	1.07801	.96064	1.04097	.99478	1.00525	9
52	.86521	1.15579	.89620	1.11582	.92817	1.07738	.96120	1.04036	.99536	1.00467	8
53	.86572	1.15511	.89672	1.11517	.92872	1.07676	.96176	1.03976	.99594	1.00408	7
54	.86623	1.15443	.89725	1.11452	.92926	1.07613	.96232	1.03915	.99652	1.00350	6
55	.86674	1.15375	.89777	1.11387	.92980	1.07550	.96288	1.03855	.99710	1.00291	5
56	.86725	1.15308	.89830	1.11321	.93034	1.07487	.96344	1.03794	.99768	1.00233	4
57	.86776	1.15240	.89883	1.11256	.93088	1.07425	.96400	1.03734	.99826	1.00175	3
58	.86827	1.15172	.89935	1.11191	.93143	1.07362	.96457	1.03674	.99884	1.00116	2
59	.86878	1.15104	.89988	1.11126	.93197	1.07299	.96513	1.03613	.99942	1.00058	1
60	.86929	1.15037	.90040	1.11061	.93252	1.07237	.96569	1.03553	1.00000	1.00000	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	49°		48°		47°		46°		45°		

TRAVERSE TABLES

OR

LATITUDES AND DEPARTURES OF COURSES

CALCULATED TO

THREE DECIMAL PLACES

FOR

EACH QUARTER DEGREE OF BEARING.

Bearing.	1		2		3		4		5	Bearing.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
0°	1.000	0.000	2.000	0.000	3.000	0.000	4.000	0.000	5.000	90°
0¼	1.000	0.004	2.000	0.009	3.000	0.013	4.000	0.017	5.000	89¾
0½	1.000	0.009	2.000	0.017	3.000	0.026	4.000	0.035	5.000	89½
0¾	1.000	0.013	2.000	0.026	3.000	0.039	4.000	0.052	5.000	89¼
1°	1.000	0.017	2.000	0.035	3.000	0.052	3.999	0.070	4.999	89°
1¼	1.000	0.022	2.000	0.044	2.999	0.065	3.999	0.087	4.999	88¾
1½	1.000	0.026	1.999	0.052	2.999	0.079	3.999	0.105	4.998	88½
1¾	1.000	0.031	1.999	0.061	2.999	0.092	3.998	0.122	4.998	88¼
2°	0.999	0.035	1.999	9.070	2.998	0.105	3.998	0.140	4.997	88°
2¼	0.999	0.039	1.998	0.079	2.998	0.118	3.997	0.157	4.996	87¾
2½	0.999	0.044	1.998	0.087	2.997	0.131	3.996	0.174	4.995	87½
2¾	0.999	0.048	1.998	0.096	2.997	0.144	3.995	0.192	4.994	87¼
3°	0.999	0.052	1.997	0.105	2.996	0.157	3.995	0.209	4.993	87°
3¼	0.998	0.057	1.997	0.113	2.995	0.170	3.994	0.227	4.992	86¾
3½	0.998	0.061	1.996	0.122	2.994	0.183	3.993	0.244	4.991	86½
3¾	0.998	0.065	1.996	0.131	2.994	0.196	3.991	0.262	4.989	86¼
4°	0.998	0.070	1.995	0.140	2.993	0.209	3.990	0.279	4.988	86°
4¼	0.997	0.074	1.995	0.148	2.992	0.222	3.989	0.296	4.986	85¾
4½	0.997	0.078	1.994	0.157	2.991	0.235	3.988	0.314	4.985	85½
4¾	0.997	0.083	1.993	0.166	2.990	0.248	3.986	0.331	4.983	85¼
5°	0.996	0.087	1.992	0.174	2.989	0.261	3.985	0.349	4.981	85°
5¼	0.996	0.092	1.992	0.183	2.987	0.275	3.983	0.366	4.979	84¾
5½	0.995	0.096	1.991	0.192	2.986	0.288	3.982	0.383	4.977	84½
5¾	0.995	0.100	1.990	0.200	2.985	0.301	3.980	0.401	4.975	84¼
6°	0.995	0.105	1.989	0.209	2.984	0.314	3.978	0.418	4.973	84°
6¼	0.994	0.109	1.988	0.218	2.982	0.327	3.976	0.435	4.970	83¾
6½	0.994	0.113	1.987	0.226	2.981	0.340	3.974	0.453	4.968	83½
6¾	0.993	0.118	1.986	0.235	2.979	0.353	3.972	0.470	4.965	83¼
7°	0.993	0.122	1.985	0.244	2.978	0.366	3.970	0.487	4.963	83°
7¼	0.992	0.126	1.984	0.252	2.976	0.379	3.968	0.505	4.960	82¾
7½	0.991	0.131	1.983	0.261	2.974	0.392	3.966	0.522	4.957	82½
7¾	0.991	0.135	1.982	0.270	2.973	0.405	3.963	0.539	4.954	82¼
8°	0.990	0.139	1.981	0.278	2.971	0.418	3.961	0.557	4.951	82°
8¼	0.990	0.143	1.979	0.287	2.969	0.430	3.959	0.574	4.948	81¾
8½	0.989	0.148	1.978	0.296	2.967	0.443	3.956	0.591	4.945	81½
8¾	0.988	0.152	1.977	0.304	2.965	0.456	3.953	0.608	4.942	81¼
9°	0.988	0.156	1.975	0.313	2.963	0.469	3.951	0.626	4.938	81°
9¼	0.987	0.161	1.974	0.321	2.961	0.482	3.948	0.643	4.935	80¾
9½	0.986	0.165	1.973	0.330	2.959	0.495	3.945	0.660	4.931	80½
9¾	0.986	0.169	1.971	0.339	2.957	0.508	3.942	0.677	4.928	80¼
10°	0.985	9.174	1.970	0.347	2.954	0.521	3.939	0.695	4.924	80°
10¼	0.984	0.178	1.968	0.356	2.952	0.534	3.936	0.712	4.920	79¾
10½	0.983	0.182	1.967	0.364	2.950	0.547	3.933	0.729	4.916	79½
10¾	0.982	0.187	1.965	0.373	2.947	0.560	3.930	0.746	4.912	79¼
11°	0.982	0.191	1.963	0.382	2.945	0.572	3.927	0.763	4.908	79°
11¼	0.981	0.195	1.962	0.390	2.942	0.585	3.923	0.780	4.904	78¾
11½	0.980	0.199	1.960	0.399	2.940	0.598	3.920	0.797	4.900	78½
11¾	0.979	0.204	1.958	0.407	2.937	0.611	3.916	0.815	4.895	78¼
12°	0.978	0.208	1.956	0.416	2.934	0.624	3.913	0.832	4.891	78°
12¼	0.977	0.212	1.954	0.424	2.932	0.637	3.909	0.849	4.886	77¾
12½	0.976	0.216	1.953	0.433	2.929	0.649	3.905	0.866	4.881	77½
12¾	0.975	0.221	1.951	0.441	2.926	0.662	3.901	0.883	4.877	77¼
13°	0.974	0.225	1.949	0.450	2.923	0.675	3.897	0.900	4.872	77°
Bearing.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Bearing.
	1		2		3		4		5	

Bearing.	5	6		7		8		9		Bearing.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
0°	0.000	6.000	0.000	7.000	0.000	8.000	0.000	9.000	0.000	90°
0¼	0.022	6.000	0.026	7.000	0.031	8.000	0.035	9.000	0.039	89¾
0½	0.044	6.000	0.052	7.000	0.061	8.000	0.070	9.000	0.079	89½
0¾	0.065	5.999	0.079	6.999	0.092	7.999	0.105	8.999	0.118	89¼
1°	0.087	5.999	0.105	6.999	0.122	7.999	0.140	8.999	0.157	89°
1¼	0.109	5.999	0.131	6.998	0.153	7.998	0.175	8.998	0.196	88¾
1½	0.131	5.998	0.157	6.998	0.183	7.997	0.209	8.997	0.236	88½
1¾	0.153	5.997	0.183	6.997	0.214	7.996	0.244	8.996	0.275	88¼
2°	0.174	5.996	0.209	6.996	0.244	7.995	0.279	8.995	0.314	88°
2¼	0.196	5.995	0.236	6.995	0.275	7.994	0.314	8.993	0.353	87¾
2½	0.218	5.994	0.262	6.993	0.305	7.992	0.349	8.991	0.393	87½
2¾	0.240	5.993	0.288	6.992	0.336	7.991	0.384	8.990	0.432	87¼
3°	0.262	5.992	0.314	6.990	0.366	7.989	0.419	8.988	0.471	87°
3¼	0.283	5.990	0.340	6.989	0.397	7.987	0.454	8.986	0.510	86¾
3½	0.305	5.989	0.366	6.987	0.427	7.985	0.488	8.983	0.549	86½
3¾	0.327	5.987	0.392	6.985	0.458	7.983	0.523	8.981	0.589	86¼
4°	0.349	5.985	0.419	6.983	0.488	7.981	0.558	8.978	0.628	86°
4¼	0.371	5.984	0.445	6.981	0.519	7.978	0.593	8.975	0.667	85¾
4½	0.392	5.982	0.471	6.978	0.549	7.975	0.628	8.972	0.706	85½
4¾	0.414	5.979	0.497	6.976	0.580	7.973	0.662	8.969	0.745	85¼
5°	0.436	5.977	0.523	6.973	0.610	7.970	0.697	8.966	0.784	85°
5¼	0.458	5.975	0.549	6.971	0.641	7.966	0.732	8.962	0.824	84¾
5½	0.479	5.972	0.575	6.968	0.671	7.963	0.767	8.959	0.863	84½
5¾	0.501	5.970	0.601	6.965	0.701	7.960	0.802	8.955	0.902	84¼
6°	0.523	5.967	0.627	6.962	0.732	7.956	0.836	8.951	0.941	84°
6¼	0.544	5.964	0.653	6.958	0.762	7.952	0.871	8.947	0.980	83¾
6½	0.566	5.961	0.679	6.955	0.792	7.949	0.906	8.942	1.019	83½
6¾	0.588	5.958	0.705	6.951	0.823	7.945	0.940	8.938	1.058	83¼
7°	0.609	5.955	0.731	6.948	0.853	7.940	0.975	8.933	1.097	83°
7¼	0.631	5.952	0.757	6.944	0.883	7.936	1.010	8.928	1.136	82¾
7½	0.653	5.949	0.783	6.940	0.914	7.932	1.044	8.923	1.175	82½
7¾	0.674	5.945	0.809	6.936	0.944	7.927	1.079	8.918	1.214	82¼
8°	0.696	5.942	0.835	6.932	0.974	7.922	1.113	8.912	1.253	82°
8¼	0.717	5.938	0.861	6.928	1.004	7.917	1.148	8.907	1.291	81¾
8½	0.739	5.934	0.887	6.923	1.035	7.912	1.182	8.901	1.330	81½
8¾	0.761	5.930	0.913	6.919	1.065	7.907	1.217	8.895	1.369	81¼
9°	0.782	5.926	0.939	6.914	1.095	7.902	1.251	8.889	1.408	81°
9¼	0.804	5.922	0.964	6.909	1.125	7.896	1.286	8.883	1.447	80¾
9½	0.825	5.918	0.990	6.904	1.155	7.890	1.320	8.877	1.485	80½
9¾	0.847	5.913	1.016	6.899	1.185	7.884	1.355	8.870	1.524	80¼
10°	0.868	5.909	1.042	6.894	1.216	7.878	1.389	8.863	1.563	80°
10¼	0.890	5.904	1.068	6.888	1.246	7.872	1.424	8.856	1.601	79¾
10½	0.911	5.900	1.093	6.883	1.276	7.866	1.458	8.849	1.640	79½
10¾	0.933	5.895	1.119	6.877	1.306	7.860	1.492	8.842	1.679	79¼
11°	0.954	5.890	1.145	6.871	1.336	7.853	1.526	8.835	1.717	79°
11¼	0.975	5.885	1.171	6.866	1.366	7.846	1.561	8.827	1.756	78¾
11½	0.997	5.880	1.196	6.859	1.396	7.839	1.595	8.819	1.794	78½
11¾	1.018	5.874	1.222	6.853	1.425	7.832	1.629	8.811	1.833	78¼
12°	1.040	5.869	1.247	6.847	1.455	7.825	1.663	8.803	1.871	78°
12¼	1.061	5.863	1.273	6.841	1.485	7.818	1.697	8.795	1.910	77¾
12½	1.082	5.858	1.299	6.834	1.515	7.810	1.732	8.787	1.948	77½
12¾	1.103	5.852	1.324	6.827	1.545	7.803	1.766	8.778	1.986	77¼
13°	1.125	5.846	1.350	6.821	1.575	7.795	1.800	8.769	2.025	77°
Bearing.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Bearing.
	5	6		7		8		9		

Bearing.	1		2		3		4		5	Bearing.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
13°	0.974	0.225	1.949	0.450	2.923	0.675	3.897	0.900	4.872	77°
13¼	0.973	0.229	1.947	0.458	2.920	0.688	3.894	0.917	4.867	76¾
13½	0.972	0.233	1.945	0.467	2.917	0.700	3.889	0.934	4.862	76½
13¾	0.971	0.238	1.943	0.475	2.914	0.713	3.885	0.951	4.857	76¼
14°	0.970	0.242	1.941	0.484	2.911	0.726	3.881	0.968	4.851	76°
14¼	0.969	0.246	1.938	0.492	2.908	0.738	3.877	0.985	4.846	75¾
14½	0.968	0.250	1.936	0.501	2.904	0.751	3.873	1.002	4.841	75½
14¾	0.967	0.255	1.934	0.509	2.901	0.764	3.868	1.018	4.835	75¼
15°	0.966	0.259	1.932	0.518	2.898	0.776	3.864	1.035	4.830	75°
15¼	0.965	0.263	1.930	0.526	2.894	0.789	3.859	1.052	4.824	74¾
15½	0.964	0.267	1.927	0.534	2.891	0.802	3.855	1.069	4.818	74½
15¾	0.962	0.271	1.925	0.543	2.887	0.814	3.850	1.086	4.812	74¼
16°	0.961	0.276	1.923	0.551	2.884	0.827	3.845	1.103	4.806	74°
16¼	0.960	0.280	1.920	0.560	2.880	0.839	3.840	1.119	4.800	73¾
16½	0.959	0.284	1.918	0.568	2.876	0.852	3.835	1.136	4.794	73½
16¾	0.958	0.288	1.915	0.576	2.873	0.865	3.830	1.153	4.788	73¼
17°	0.956	0.292	1.913	0.585	2.869	0.877	3.825	1.169	4.782	73°
17¼	0.955	0.297	1.910	0.593	2.865	0.890	3.820	1.186	4.775	72¾
17½	0.954	0.301	1.907	0.601	2.861	0.902	3.815	1.203	4.769	72½
17¾	0.952	0.305	1.905	0.610	2.857	0.915	3.810	1.220	4.762	72¼
18°	0.951	0.309	1.902	0.618	2.853	0.927	3.804	1.236	4.755	72°
18¼	0.950	0.313	1.899	0.626	2.849	0.939	3.799	1.253	4.748	71¾
18½	0.948	0.317	1.897	0.635	2.845	0.952	3.793	1.269	4.742	71½
18¾	0.947	0.321	1.894	0.643	2.841	0.964	3.788	1.286	4.735	71¼
19°	0.946	0.326	1.891	0.651	2.837	0.977	3.782	1.302	4.728	71°
19¼	0.944	0.330	1.888	0.659	2.832	0.989	3.776	1.319	4.720	70¾
19½	0.943	0.334	1.885	0.668	2.828	1.001	3.771	1.335	4.713	70½
19¾	0.941	0.338	1.882	0.676	2.824	1.014	3.765	1.352	4.706	70¼
20°	0.940	0.342	1.879	0.684	2.819	1.026	3.759	1.368	4.698	70°
20¼	0.938	0.346	1.876	0.692	2.815	1.038	3.753	1.384	4.691	69¾
20½	0.937	0.350	1.873	0.700	2.810	1.051	3.747	1.401	4.683	69½
20¾	0.935	0.354	1.870	0.709	2.805	1.063	3.741	1.417	4.676	69¼
21°	0.934	0.358	1.867	0.717	2.801	1.075	3.734	1.433	4.668	69°
21¼	0.932	0.362	1.864	0.725	2.796	1.087	3.728	1.450	4.660	68¾
21½	0.930	0.367	1.861	0.733	2.791	1.100	3.722	1.466	4.652	68½
21¾	0.929	0.371	1.858	0.741	2.786	1.112	3.715	1.482	4.644	68¼
22°	0.927	0.375	1.854	0.749	2.782	1.124	3.709	1.498	4.636	68°
22¼	0.926	0.379	1.851	0.757	2.777	1.136	3.702	1.515	4.628	67¾
22½	0.924	0.383	1.848	0.765	2.772	1.148	3.696	1.531	4.619	67½
22¾	0.922	0.387	1.844	0.773	2.767	1.160	3.689	1.547	4.611	67¼
23°	0.921	0.391	1.841	0.781	2.762	1.172	3.682	1.563	4.603	67°
23¼	0.919	0.395	1.838	0.789	2.756	1.184	3.675	1.579	4.594	66¾
23½	0.917	0.399	1.834	0.797	2.751	1.196	3.668	1.595	4.585	66½
23¾	0.915	0.403	1.831	0.805	2.746	1.208	3.661	1.611	4.577	66¼
24°	0.914	0.407	1.827	0.813	2.741	1.220	3.654	1.627	4.568	66°
24¼	0.912	0.411	1.824	0.821	2.735	1.232	3.647	1.643	4.559	65¾
24½	0.910	0.415	1.820	0.829	2.730	1.244	3.640	1.659	4.550	65½
24¾	0.908	0.419	1.816	0.837	2.724	1.256	3.633	1.675	4.541	65¼
25°	0.906	0.423	1.813	0.845	2.719	1.268	3.625	1.690	4.532	65°
25¼	0.904	0.427	1.809	0.853	2.713	1.280	3.618	1.706	4.522	64¾
25½	0.903	0.431	1.805	0.861	2.708	1.292	3.610	1.722	4.513	64½
25¾	0.901	0.434	1.801	0.869	2.702	1.303	3.603	1.738	4.503	64¼
26°	0.899	0.438	1.798	0.877	2.696	1.315	3.595	1.753	4.494	64°
Bearing.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Bearing.
	1		2		3		4		5	

Bearing.	5	6		7		8		9		Bearing.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
13°	1.125	5.846	1.350	6.821	1.575	7.795	1.800	8.769	2.025	77°
13¼	1.146	5.840	1.375	6.814	1.604	7.787	1.834	8.760	2.063	76¾
13½	1.167	5.834	1.401	6.807	1.634	7.779	1.868	8.751	2.101	76½
13¾	1.188	5.828	1.426	6.799	1.664	7.771	1.902	8.742	2.139	76¼
14°	1.210	5.822	1.452	6.792	1.693	7.762	1.935	8.733	2.177	76°
14¼	1.231	5.815	1.477	6.785	1.723	7.754	1.969	8.723	2.215	75¾
14½	1.252	5.809	1.502	6.777	1.753	7.745	2.003	8.713	2.253	75½
14¾	1.273	5.802	1.528	6.769	1.782	7.736	2.037	8.703	2.291	75¼
15°	1.294	5.796	1.553	6.761	1.812	7.727	2.071	8.693	2.329	75°
15¼	1.315	5.789	1.578	6.754	1.841	7.718	2.104	8.683	2.367	74¾
15½	1.336	5.782	1.603	6.745	1.871	7.709	2.138	8.673	2.405	74½
15¾	1.357	5.775	1.629	6.737	1.900	7.700	2.172	8.662	2.443	74¼
16°	1.378	5.768	1.654	6.729	1.929	7.690	2.205	8.651	2.481	74°
16¼	1.399	5.760	1.679	6.720	1.959	7.680	2.239	8.640	2.518	73¾
16½	1.420	5.753	1.704	6.712	1.988	7.671	2.272	8.629	2.556	73½
16¾	1.441	5.745	1.729	6.703	2.017	7.661	2.306	8.618	2.594	73¼
17°	1.462	5.738	1.754	6.694	2.047	7.650	2.339	8.607	2.631	73°
17¼	1.483	5.730	1.779	6.685	2.076	7.640	2.372	8.595	2.669	72¾
17½	1.504	5.722	1.804	6.676	2.105	7.630	2.406	8.583	2.706	72½
17¾	1.524	5.714	1.829	6.667	2.134	7.619	2.439	8.572	2.744	72¼
18°	1.545	5.706	1.854	6.657	2.163	7.608	2.472	8.560	2.781	72°
18¼	1.566	5.698	1.879	6.648	2.192	7.598	2.505	8.547	2.818	71¾
18½	1.587	5.690	1.904	6.638	2.221	7.587	2.538	8.535	2.856	71½
18¾	1.607	5.682	1.929	6.629	2.250	7.575	2.572	8.522	2.893	71¼
19°	1.628	5.673	1.953	6.619	2.279	7.564	2.605	8.510	2.930	71°
19¼	1.648	5.665	1.978	6.609	2.308	7.553	2.638	8.497	2.967	70¾
19½	1.669	5.656	2.003	6.598	2.337	7.541	2.670	8.484	3.004	70½
19¾	1.690	5.647	2.028	6.588	2.365	7.529	2.703	8.471	3.041	70¼
20°	1.710	5.638	2.052	6.578	2.394	7.518	2.736	8.457	3.078	70°
20¼	1.731	5.629	2.077	6.567	2.423	7.506	2.769	8.444	3.115	69¾
20½	1.751	5.620	2.101	6.557	2.451	7.493	2.802	8.430	3.152	69½
20¾	1.771	5.611	2.126	6.546	2.480	7.481	2.834	8.416	3.189	69¼
21°	1.792	5.601	2.150	6.535	2.509	7.469	2.867	8.402	3.225	69°
21¼	1.812	5.592	2.175	6.524	2.537	7.456	2.900	8.388	3.262	68¾
21½	1.833	5.582	2.199	6.513	2.566	7.443	2.932	8.374	3.299	68½
21¾	1.853	5.573	2.223	6.502	2.594	7.430	2.964	8.359	3.335	68¼
22°	1.873	5.563	2.248	6.490	2.622	7.417	2.997	8.345	3.371	68°
22¼	1.893	5.553	2.272	6.479	2.651	7.404	3.029	8.330	3.408	67¾
22½	1.913	5.543	2.296	6.467	2.679	7.391	3.061	8.315	3.444	67½
22¾	1.934	5.533	2.320	6.455	2.707	7.378	3.094	8.300	3.480	67¼
23°	1.954	5.523	2.344	6.444	2.735	7.364	3.126	8.285	3.517	67°
23¼	1.974	5.513	2.368	6.432	2.763	7.350	3.158	8.269	3.553	66¾
23½	1.994	5.502	2.392	6.419	2.791	7.336	3.190	8.254	3.589	66½
23¾	2.014	5.492	2.416	6.407	2.819	7.322	3.222	8.238	3.625	66¼
24°	2.034	5.481	2.440	6.395	2.847	7.308	3.254	8.222	3.661	66°
24¼	2.054	5.471	2.464	6.382	2.875	7.294	3.286	8.206	3.696	65¾
24½	2.073	5.460	2.488	6.370	2.903	7.280	3.318	8.190	3.732	65½
24¾	2.093	5.449	2.512	6.357	2.931	7.265	3.349	8.173	3.768	65¼
25°	2.113	5.438	2.536	6.344	2.958	7.250	3.381	8.157	3.804	65°
25¼	2.133	5.427	2.559	6.331	2.986	7.236	3.413	8.140	3.839	64¾
25½	2.153	5.416	2.583	6.318	3.014	7.221	3.444	8.123	3.875	64½
25¾	2.172	5.404	2.607	6.305	3.041	7.206	3.476	8.106	3.910	64¼
26°	2.192	5.393	2.630	6.292	3.069	7.190	3.507	8.089	3.945	64°
Bearing.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Bearing.
	5	6		7		8		9		

Bearing.	1		2		3		4		5	Bearing.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
26°	0.899	0.438	1.798	0.877	2.696	1.315	3.595	1.753	4.494	64°
26¼	0.897	0.442	1.794	0.885	2.691	1.327	3.587	1.769	4.484	63¾
26½	0.895	0.446	1.790	0.892	2.685	1.339	3.580	1.785	4.475	63½
26¾	0.893	0.450	1.786	0.900	2.679	1.350	3.572	1.800	4.465	63¼
27°	0.891	0.454	1.782	0.908	2.673	1.362	3.564	1.816	4.455	63°
27¼	0.889	0.458	1.778	0.916	2.667	1.374	3.556	1.831	4.445	62¾
27½	0.887	0.462	1.774	0.923	2.661	1.385	3.548	1.847	4.435	62½
27¾	0.885	0.466	1.770	0.931	2.655	1.397	3.540	1.862	4.425	62¼
28°	0.883	0.469	1.766	0.939	2.649	1.408	3.532	1.878	4.415	62°
28¼	0.881	0.473	1.762	0.947	2.643	1.420	3.524	1.893	4.404	61¾
28½	0.879	0.477	1.758	0.954	2.636	1.431	3.515	1.909	4.394	61½
28¾	0.877	0.481	1.753	0.962	2.630	1.443	3.507	1.924	4.384	61¼
29°	0.875	0.485	1.749	0.970	2.624	1.454	3.498	1.939	4.373	61°
29¼	0.872	0.489	1.745	0.977	2.617	1.466	3.490	1.954	4.362	60¾
29½	0.870	0.492	1.741	0.985	2.611	1.477	3.481	1.970	4.352	60½
29¾	0.868	0.496	1.736	0.992	2.605	1.489	3.473	1.985	4.341	60¼
30°	0.866	0.500	1.732	1.000	2.598	1.500	3.464	2.000	4.330	60°
30¼	0.864	0.504	1.728	1.008	2.592	1.511	3.455	2.015	4.319	59¾
30½	0.862	0.508	1.723	1.015	2.585	1.523	3.447	2.030	4.308	59½
30¾	0.859	0.511	1.719	1.023	2.578	1.534	3.438	2.045	4.297	59¼
31°	0.857	0.515	1.714	1.030	2.572	1.545	3.429	2.060	4.286	59°
31¼	0.855	0.519	1.710	1.038	2.565	1.556	3.420	2.075	4.275	58¾
31½	0.853	0.522	1.705	1.045	2.558	1.567	3.411	2.090	4.263	58½
31¾	0.850	0.526	1.701	1.052	2.551	1.579	3.401	2.105	4.252	58¼
32°	0.848	0.530	1.696	1.060	2.544	1.590	3.392	2.120	4.240	58°
32¼	0.846	0.534	1.691	1.067	2.537	1.601	3.383	2.134	4.229	57¾
32½	0.843	0.537	1.687	1.075	2.530	1.612	3.374	2.149	4.217	57½
32¾	0.841	0.541	1.682	1.082	2.523	1.623	3.364	2.164	4.205	57¼
33°	0.839	0.545	1.677	1.089	2.516	1.634	3.355	2.179	4.193	57°
33¼	0.836	0.548	1.673	1.097	2.509	1.645	3.345	2.193	4.181	56¾
33½	0.834	0.552	1.668	1.104	2.502	1.656	3.336	2.208	4.169	56½
33¾	0.831	0.556	1.663	1.111	2.494	1.667	3.326	2.222	4.157	56¼
34°	0.829	0.559	1.658	1.118	2.487	1.678	3.316	2.237	4.145	56°
34¼	0.827	0.563	1.653	1.126	2.480	1.688	3.306	2.251	4.133	55¾
34½	0.824	0.566	1.648	1.133	2.472	1.699	3.297	2.266	4.121	55½
34¾	0.822	0.570	1.643	1.140	2.465	1.710	3.287	2.280	4.108	55¼
35°	0.819	0.574	1.638	1.147	2.457	1.721	3.277	2.294	4.096	55°
35¼	0.817	0.577	1.633	1.154	2.450	1.731	3.267	2.309	4.083	54¾
35½	0.814	0.581	1.628	1.161	2.442	1.742	3.257	2.323	4.071	54½
35¾	0.812	0.584	1.623	1.168	2.435	1.753	3.246	2.337	4.058	54¼
36°	0.809	0.588	1.618	1.176	2.427	1.763	3.236	2.351	4.045	54°
36¼	0.806	0.591	1.613	1.183	2.419	1.774	3.226	2.365	4.032	53¾
36½	0.804	0.595	1.608	1.190	2.412	1.784	3.215	2.379	4.019	53½
36¾	0.801	0.598	1.603	1.197	2.404	1.795	3.205	2.393	4.006	53¼
37°	0.799	0.602	1.597	1.204	2.396	1.805	3.195	2.407	3.993	53°
37¼	0.796	0.605	1.592	1.211	2.388	1.816	3.184	2.421	3.980	52¾
37½	0.793	0.609	1.587	1.218	2.380	1.826	3.173	2.435	3.967	52½
37¾	0.791	0.612	1.581	1.224	2.372	1.837	3.163	2.449	3.953	52¼
38°	0.788	0.616	1.576	1.231	2.364	1.847	3.152	2.463	3.940	52°
38¼	0.785	0.619	1.571	1.238	2.356	1.857	3.141	2.476	3.927	51¾
38½	0.783	0.623	1.565	1.245	2.348	1.868	3.130	2.490	3.913	51½
38¾	0.780	0.626	1.560	1.252	2.340	1.878	3.120	2.504	3.899	51¼
39°	0.777	0.629	1.554	1.259	2.331	1.888	3.109	2.517	3.886	51°
Bearing.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Bearing.
	1		2		3		4		5	

Bearing.	5	6		7		8		9		Bearing.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
26°	2.192	5.393	2.630	6.292	3.069	7.190	3.507	8.089	3.945	64°
26¼	2.211	5.381	2.654	6.278	3.096	7.175	3.538	8.072	3.981	63¾
26½	2.231	5.370	2.677	6.265	3.123	7.160	3.570	8.054	4.016	63½
26¾	2.250	5.358	2.701	6.251	3.151	7.144	3.601	8.037	4.051	63¼
27°	2.270	5.346	2.724	6.237	3.178	7.128	3.632	8.019	4.086	63°
27¼	2.289	5.334	2.747	6.223	3.205	7.112	3.663	8.001	4.121	62¾
27½	2.309	5.322	2.770	6.209	3.232	7.096	3.694	7.983	4.156	62½
27¾	2.328	5.310	2.794	6.195	3.259	7.080	3.725	7.965	4.190	62¼
28°	2.347	5.298	2.817	6.181	3.286	7.064	3.756	7.947	4.225	62°
28¼	2.367	5.285	2.840	6.166	3.313	7.047	3.787	7.928	4.260	61¾
28½	2.386	5.273	2.863	6.152	3.340	7.031	3.817	7.909	4.294	61½
28¾	2.405	5.260	2.886	6.137	3.367	7.014	3.848	7.891	4.329	61¼
29°	2.424	5.248	2.909	6.122	3.394	6.997	3.878	7.872	4.363	61°
29¼	2.443	5.235	2.932	6.107	3.420	6.980	3.909	7.852	4.398	60¾
29½	2.462	5.222	2.955	6.093	3.447	6.963	3.939	7.833	4.432	60½
29¾	2.481	5.209	2.977	6.077	3.474	6.946	3.970	7.814	4.466	60¼
30°	2.500	5.196	3.000	6.062	3.500	6.928	4.000	7.794	4.500	60°
30¼	2.519	5.183	3.023	6.047	3.526	6.911	4.030	7.775	4.534	59¾
30½	2.538	5.170	3.045	6.031	3.553	6.893	4.060	7.755	4.568	59½
30¾	2.556	5.156	3.068	6.016	3.579	6.875	4.090	7.735	4.602	59¼
31°	2.575	5.143	3.090	6.000	3.605	6.857	4.120	7.715	4.635	59°
31¼	2.594	5.129	3.113	5.984	3.631	6.839	4.150	7.694	4.669	58¾
31½	2.612	5.116	3.135	5.968	3.657	6.821	4.180	7.674	4.702	58½
31¾	2.631	5.102	3.157	5.952	3.683	6.803	4.210	7.653	4.736	58¼
32°	2.650	5.088	3.180	5.936	3.709	6.784	4.239	7.632	4.769	58°
32¼	2.668	5.074	3.202	5.920	3.735	6.766	4.269	7.612	4.802	57¾
32½	2.686	5.060	3.224	5.904	3.761	6.747	4.298	7.591	4.836	57½
32¾	2.705	5.046	3.246	5.887	3.787	6.728	4.328	7.569	4.869	57¼
33°	2.723	5.032	3.268	5.871	3.812	6.709	4.357	7.548	4.902	57°
33¼	2.741	5.018	3.290	5.854	3.838	6.690	4.386	7.527	4.935	56¾
33½	2.760	5.003	3.312	5.837	3.864	6.671	4.416	7.505	4.967	56½
33¾	2.778	4.989	3.333	5.820	3.889	6.652	4.445	7.483	5.000	56¼
34°	2.796	4.974	3.355	5.803	3.914	6.632	4.474	7.461	5.033	56°
34¼	2.814	4.960	3.377	5.786	3.940	6.613	4.502	7.439	5.065	55¾
34½	2.832	4.945	3.398	5.769	3.965	6.593	4.531	7.417	5.098	55½
34¾	2.850	4.930	3.420	5.752	3.990	6.573	4.560	7.395	5.130	55¼
35°	2.868	4.915	3.441	5.734	4.015	6.553	4.589	7.372	5.162	55°
35¼	2.886	4.900	3.463	5.716	4.040	6.533	4.617	7.350	5.194	54¾
35½	2.904	4.885	3.484	5.699	4.065	6.513	4.646	7.327	5.226	54½
35¾	2.921	4.869	3.505	5.681	4.090	6.493	4.674	7.304	5.258	54¼
36°	2.939	4.854	3.527	5.663	4.115	6.472	4.702	7.281	5.290	54°
36¼	2.957	4.839	3.548	5.645	4.139	6.452	4.730	7.258	5.322	53¾
36½	2.974	4.823	3.569	5.627	4.164	6.431	4.759	7.235	5.353	53½
36¾	2.992	4.808	3.590	5.609	4.188	6.410	4.787	7.211	5.385	53¼
37°	3.009	4.792	3.611	5.590	4.213	6.389	4.815	7.188	5.416	53°
37¼	3.026	4.776	3.632	5.572	4.237	6.368	4.842	7.164	5.448	52¾
37½	3.044	4.760	3.653	5.554	4.261	6.347	4.870	7.140	5.479	52½
37¾	3.061	4.744	3.673	5.535	4.286	6.326	4.898	7.116	5.510	52¼
38°	3.078	4.728	3.694	5.516	4.310	6.304	4.925	7.092	5.541	52°
38¼	3.095	4.712	3.715	5.497	4.334	6.283	4.953	7.068	5.572	51¾
38½	3.113	4.696	3.735	5.478	4.358	6.261	4.980	7.043	5.603	51½
38¾	3.130	4.679	3.756	5.459	4.381	6.239	5.007	7.019	5.633	51¼
39°	3.147	4.663	3.776	5.440	4.405	6.217	5.035	6.994	5.664	51°
Bearing.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Bearing.
	5	6		7		8		9		

Bearing.	1		2		3		4		5	Bearing.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
39°	0.777	0.629	1.554	1.259	2.331	1.888	3.109	2.517	3.886	51°
39¼	0.774	0.633	1.549	1.265	2.323	1.898	3.098	2.531	3.872	50¾
39½	0.772	0.636	1.543	1.272	2.315	1.908	3.086	2.544	3.858	50½
39¾	0.769	0.639	1.538	1.279	2.307	1.918	3.075	2.558	3.844	50¼
40°	0.766	0.643	1.532	1.286	2.298	1.928	3.064	2.571	3.830	50°
40¼	0.763	0.646	1.526	1.292	2.290	1.938	3.053	2.584	3.816	49¾
40½	0.760	0.649	1.521	1.299	2.281	1.948	3.042	2.598	3.802	49½
40¾	0.758	0.653	1.515	1.306	2.273	1.958	3.030	2.611	3.788	49¼
41°	0.755	0.656	1.509	1.312	2.264	1.968	3.019	2.624	3.774	49°
41¼	0.752	0.659	1.504	1.319	2.256	1.978	3.007	2.637	3.759	48¾
41½	0.749	0.663	1.498	1.325	2.247	1.988	2.996	2.650	3.745	48½
41¾	0.746	0.666	1.492	1.332	2.238	1.998	2.984	2.664	3.730	48¼
42°	0.743	0.669	1.486	1.338	2.229	2.007	2.973	2.677	3.716	48°
42¼	0.740	0.672	1.480	1.345	2.221	2.017	2.961	2.689	3.701	47¾
42½	0.737	0.676	1.475	1.351	2.212	2.027	2.949	2.702	3.686	47½
42¾	0.734	0.679	1.469	1.358	2.203	2.036	2.937	2.715	3.672	47¼
43°	0.731	0.682	1.463	1.364	2.194	2.046	2.925	2.728	3.657	47°
43¼	0.728	0.685	1.457	1.370	2.185	2.056	2.913	2.741	3.642	46¾
43½	0.725	0.688	1.451	1.377	2.176	2.065	2.901	2.753	3.627	46½
43¾	0.722	0.692	1.445	1.383	2.167	2.075	2.889	2.766	3.612	46¼
44°	0.719	0.695	1.439	1.389	2.158	2.084	2.877	2.779	3.597	46°
44¼	0.716	0.698	1.433	1.396	2.149	2.093	2.865	2.791	3.582	45¾
44½	0.713	0.701	1.427	1.402	2.140	2.103	2.853	2.804	3.566	45½
44¾	0.710	0.704	1.420	1.408	2.131	2.112	2.841	2.816	3.551	45¼
45°	0.707	0.707	1.414	1.414	2.121	2.121	2.828	2.828	3.536	45°
B'ring	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	B'ring

Bearing.	5	6		7		8		9		Bearing.
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
39°	3.147	4.663	3.776	5.440	4.405	6.217	5.035	6.994	5 664	51°
39¼	3.164	4.646	3.796	5.421	4.429	6.195	5.062	6.970	5.694	50¾
39½	3.180	4.630	3.816	5.401	4.453	6.173	5.089	6.945	5.725	50½
39¾	3.197	4.613	3 837	5.382	4.476	6.151	5.116	6.920	5.755	50¼
40°	3.214	4.596	3.857	5.362	4.500	6.128	5.142	6.894	5.785	50°
40¼	3.231	4.579	3.877	5.343	4.523	6.106	5.169	6.869	5.815	49¾
40½	3.247	4.562	3.897	5.323	4.546	6.083	5.196	6.844	5.845	49½
40¾	3.264	4.545	3.917	5.303	4.569	6.061	5.222	6.818	5.875	49¼
41°	3.280	4.528	3.936	5.283	4.592	6 038	5.248	6.792	5.905	49°
41¼	3.297	4.511	3.956	5.263	4.615	6.015	5.275	6.767	5.934	48¾
41½	3.313	4.494	3.976	5.243	4.638	5.992	5.301	6.741	5.964	48½
41¾	3.329	4.476	3.995	5.222	4.661	5.968	5.327	6.715	5.993	48¼
42°	3.346	4.459	4.015	5.202	4.684	5.945	5.353	6.688	6.022	48°
42¼	3.362	4.441	4.034	5.182	4.707	5.922	5.379	6.662	6.051	47¾
42½	3.378	4.424	4.054	5.161	4.729	5.898	5.405	6.635	6.080	47½
42¾	3.394	4.406	4.073	5.140	4.752	5.875	5.430	6.609	6.109	47¼
43°	3.410	4.388	4.092	5.119	4.774	5.851	5.456	6.582	6.138	47°
43¼	3.426	4.370	4.111	5.099	4.796	5 827	5.481	6.555	6.167	46¾
43½	3.442	4.352	4.130	5.078	4 818	5 803	5.507	6 528	6.195	46½
43¾	3.458	4.334	4.149	5.057	4.841	5.779	5.532	6.501	6.224	46¼
44°	3.473	4.316	4.168	5.035	4.863	5.755	5.557	6.474	6.252	46°
44¼	3.489	4.298	4.187	5.014	4 885	5.730	5.582	6.447	6.280	45¾
44½	3.505	4.280	4.206	4.993	4.906	5.706	5.607	6.419	6.308	45½
44¾	3.520	4.261	4.224	4.971	4.928	5.681	5.632	6.392	6.336	45¼
45°	3.536	4.243	4.243	4.950	4.950	5.657	5.657	6.364	6.364	45°
B'ring	Lat.	Dep.	Lat	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	B'ring

TABLES OF THE AVERAGE RESISTING VALUES OF MATERIALS COMMONLY USED IN ENGINEERING CONSTRUCTION.

AVERAGE VALUES IN TENSION.

MATERIAL.	Coefficient of Elasticity. E_1.	Elastic Limit. L_1.	Ultimate Tensile Strength. S_1.	Ultimate Elongation. s_1.
	Lb. per Sq. In.	Lb. per Sq. In.	Lb. per Sq. In.	Inch per Linear Inch.
Timber.....	1,500,000	3,000	10,000	0.015
Cast Iron.....	15,000,000	6,000	20,000	0.005
Wrought Iron.	25,000,000	25,000	55,000	0.20
Steel.....	30,000,000	50,000	100,000	0.10

AVERAGE VALUES IN COMPRESSION.

MATERIAL.	Coefficient of Elasticity. E_2.	Elastic Limit. L_2.	Ultimate Compressive Strength. S_2.
	Lb. per Sq. In.	Lb. per Sq. In.	Lb. per Sq. In.
Timber.....	1,500,000	3,000	8,000
Brick.....			2,500
Stone.....	6,000,000		6,000
Cast Iron.....	15,000,000		90,000
Wrought Iron.....	25,000,000	25,000	55,000
Steel.....	30,000,000	50,000	150,000

AVERAGE VALUES IN SHEAR.

Material.	Coefficient of Elasticity. E_s.	Ultimate Shearing Strength. S_s.
Timber (across the grain)		3,000
Timber (with the grain)	400,000	600
Cast Iron	6,000,000	20,000
Wrought Iron	15,000,000	50,000
Steel		70,000

ULTIMATE STRENGTH IN FLEXURE.

Material.	Ultimate Strength of Flexure in Lb. per Sq. In. S_f.
Cast Iron	38,000
Wrought Iron	45,000
Steel	120,000
Brass	17,000
Ash	14,000
Brick	1,000
Stone	2,000
Hemlock	7,200
Oak, white	12,500
Pine, white	9,000
Pine, yellow	11,000
Hickory	16,000

FACTORS OF SAFETY TO BE USED IN CONNECTION WITH THE FOUR PRECEDING TABLES.

Material.	For Steady Stress. (Buildings.)	For Varying Stress. (Bridges.)	For Shocks. (Machines.)
Timber	8	10	15
Brick and Stone	15	25	30
Cast Iron	6	10	15
Wrought Iron	4	6	10
Steel	5	7	10

TABLE OF

HORIZONTAL DISTANCES AND DIFFERENCES OF ELEVATION FOR STADIA MEASUREMENTS.

The formulas used in the computation of the following tables furnish expressions for *horizontal distances* and *differences of elevation* for stadia measurements with the conditions that the stadia rod *be held vertical* and the stadia wires be *equidistant* from the center wire. The formulas used are as follows: For the horizontal distance

$$D = c \cos n + a k \cos^2 n, \qquad \textbf{(94.)}$$ Art. **1301.**

in which D = the corrected distance; c = the constant; $a k$ = the stadia distance, and n = the vertical angle.

For the difference of elevation, the following formula is used:

$$E = c \sin n + a k \frac{\sin 2n}{2}. \qquad \textbf{(95.)}$$ Art. **1301.**

For application of tables see Art. **1301.**

HORIZONTAL DISTANCES AND DIFFERENCES OF ELEVATION FOR STADIA MEASUREMENTS.

Minutes.	0°		1°		2°		3°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0'	100.00	.00	99.97	1.74	99.88	3.49	99.73	5.23
2	100.00	.06	99.97	1.80	99.87	3.55	99.72	5.28
4	100.00	.12	99.97	1.86	99.87	3.60	99.71	5.34
6	100.00	.17	99.96	1.92	99.87	3.66	99.71	5.40
8	100.00	.23	99.96	1.98	99.86	3.72	99.70	5.46
10	100.00	.29	99.96	2.04	99.86	3.78	99.69	5.52
12	100.00	.35	99.96	2.09	99.85	3.84	99.69	5.57
14	100.00	.41	99.95	2.15	99.85	3.90	99.68	5.63
16	100.00	.47	99.95	2.21	99.84	3.95	99.68	5.69
18	100.00	.52	99.95	2.27	99.84	4.01	99.67	5.75
20	100.00	.58	99.95	2.33	99.83	4.07	99.66	5.80
22	100.00	.64	99.94	2.38	99.83	4.13	99.66	5.86
24	100.00	.70	99.94	2.44	99.82	4.18	99.65	5.92
26	99.99	.76	99.94	2.50	99.82	4.24	99.64	5.98
28	99.99	.81	99.93	2.56	99.81	4.30	99.63	6.04
30	99.99	.87	99.93	2.62	99.81	4.36	99.63	6.09
32	99.99	.93	99.93	2.67	99.80	4.42	99.62	6.15
34	99.99	.99	99.93	2.73	99.80	4.48	99.62	6.21
36	99.99	1.05	99.92	2.79	99.79	4.53	99.61	6.27
38	99.99	1.11	99.92	2.85	99.79	4.59	99.60	6.33
40	99.99	1.16	99.92	2.91	99.78	4.65	99.59	6.38
42	99.99	1.22	99.91	2.97	99.78	4.71	99.59	6.44
44	99.98	1.28	99.91	3.02	99.77	4.76	99.58	6.50
46	99.98	1.34	99.90	3.08	99.77	4.82	99.57	6.56
48	99.98	1.40	99.90	3.14	99.76	4.88	99.56	6.61
50	99.98	1.45	99.90	3.20	99.76	4.94	99.56	6.67
52	99.98	1.51	99.89	3.26	99.75	4.99	99.55	6.73
54	99.98	1.57	99.89	3.31	99.74	5.05	99.54	6.78
56	99.97	1.63	99.89	3.37	99.74	5.11	99.53	6.84
58	99.97	1.69	99.88	3.43	99.73	5.17	99.52	6.90
60	99.97	1.74	99.88	3.49	99.73	5.23	99.51	6.96
c = .75	.75	.01	.75	.02	.75	.03	.75	.05
c = 1.00	1.00	.01	1.00	.03	1.00	.04	1.00	.06
c = 1.25	1.25	.02	1.25	.03	1.25	.05	1.25	.08

HORIZONTAL DISTANCES AND DIFFERENCES OF ELEVATION FOR STADIA MEASUREMENTS.

Minutes.	4°		5°		6°		7°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0'	99.51	6.96	99.24	8.68	98.91	10.40	98.51	12.10
2	99.51	7.02	99.23	8.74	98.90	10.45	98.50	12.15
4	99.50	7.07	99.22	8.80	98.88	10.51	98.48	12.21
6	99.49	7.13	99.21	8.85	98.87	10.57	98.47	12.26
8	99.48	7.19	99.20	8.91	98.86	10.62	98.46	12.32
10	99.47	7.25	99.19	8.97	98.85	10.68	98.44	12.38
12	99.46	7.30	99.18	9.03	98.83	10.74	98.43	12.43
14	99.46	7.36	99.17	9.08	98.82	10.79	98.41	12.49
16	99.45	7.42	99.16	9.14	98.81	10.85	98.40	12.55
18	99.44	7.48	99.15	9.20	98.80	10.91	98.39	12.60
20	99.43	7.53	99.14	9.25	98.78	10.96	98.37	12.66
22	99.42	7.59	99.13	9.31	98.77	11.02	98.36	12.72
24	99.41	7.65	99.11	9.37	98.76	11.08	98.34	12.77
26	99.40	7.71	99.10	9.43	98.74	11.13	98.33	12.83
28	99.39	7.76	99.09	9.48	98.73	11.19	98.31	12.88
30	99.38	7.82	99.08	9.54	98.72	11.25	98.29	12.94
32	99.38	7.88	99.07	9.60	98.71	11.30	98.28	13.00
34	99.37	7.94	99.06	9.65	98.69	11.36	98.27	13.05
36	99.36	7.99	99.05	9.71	98.68	11.42	98.25	13.11
38	99.35	8.05	99.04	9.77	98.67	11.47	98.24	13.17
40	99.34	8.11	99.03	9.83	98.65	11.53	98.22	13.22
42	99.33	8.17	99.01	9.88	98.64	11.59	98.20	13.28
44	99.32	8.22	99.00	9.94	98.63	11.64	98.19	13.33
46	99.31	8.28	98.99	10.00	98.61	11.70	98.17	13.39
48	99.30	8.34	98.98	10.05	98.60	11.76	98.16	13.45
50	99.29	8.40	98.97	10.11	98.58	11.81	98.14	13.50
52	99.28	8.45	98.96	10.17	98.57	11.87	98.13	13.56
54	99.27	8.51	98.94	10.22	98.56	11.93	98.11	13.61
56	99.26	8.57	98.93	10.28	98.54	11.98	98.10	13.67
58	99.25	8.63	98.92	10.34	98.53	12.04	98.08	13.73
60	99.24	8.68	98.91	10.40	98.51	12.10	98.06	13.78
c = .75	.75	.06	.75	.07	.75	.08	.74	.10
c = 1.00	1.00	.08	.99	.09	.99	.11	.99	.13
c = 1.25	1.25	.10	1.24	.11	1.24	.14	1.24	.16

HORIZONTAL DISTANCES AND DIFFERENCES OF ELEVATION FOR STADIA MEASUREMENTS.

Minutes.	8°		9°		10°		11°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0'	98.06	13.78	97.55	15.45	96.98	17.10	96.36	18.73
2	98.05	13.84	97.53	15.51	96.96	17.16	96.34	18.78
4	98.03	13.89	97.52	15.56	96.94	17.21	96.32	18.84
6	98.01	13.95	97.50	15.62	96.92	17.26	96.29	18.89
8	98.00	14.01	97.48	15.67	96.90	17.32	96.27	18.95
10	97.98	14.06	97.46	15.73	96.88	17.37	96.25	19.00
12	97.97	14.12	97.44	15.78	96.86	17.43	96.23	19.05
14	97.95	14.17	97.43	15.84	96.84	17.48	96.21	19.11
16	97.93	14.23	97.41	15.89	96.82	17.54	96.18	19.16
18	97.92	14.28	97.39	15.95	96.80	17.59	96.16	19.21
20	97.90	14.34	97.37	16.00	96.78	17.65	96.14	19.27
22	97.88	14.40	97.35	16.06	96.76	17.70	96.12	19.32
24	97.87	14.45	97.33	16.11	96.74	17.76	96.09	19.38
26	97.85	14.51	97.31	16.17	96.72	17.81	96.07	19.43
28	97.83	14.56	97.29	16.22	96.70	17.86	96.05	19.48
30	97.82	14.62	97.28	16.28	96.68	17.92	96.03	19.54
32	97.80	14.67	97.26	16.33	96.66	17.97	96.00	19.59
34	97.78	14.73	97.24	16.39	96.64	18.03	95.98	19.64
36	97.76	14.79	97.22	16.44	96.62	18.08	95.96	19.70
38	97.75	14.84	97.20	16.50	96.60	18.14	95.93	19.75
40	97.73	14.90	97.18	16.55	96.57	18.19	95.91	19.80
42	97.71	14.95	97.16	16.61	96.55	18.24	95.89	19.86
44	97.69	15.01	97.14	16.66	96.53	18.30	95.86	19.91
46	97.68	15.06	97.12	16.72	96.51	18.35	95.84	19.96
48	97.66	15.12	97.10	16.77	96.49	18.41	95.82	20.02
50	97.64	15.17	97.08	16.83	96.47	18.46	95.79	20.07
52	97.62	15.23	97.06	16.88	96.45	18.51	95.77	20.12
54	97.61	15.28	97.04	16.94	96.42	18.57	95.75	20.18
56	97.59	15.34	97.02	16.99	96.40	18.62	95.72	20.23
58	97.57	15.40	97.00	17.05	96.38	18.68	95.70	20.28
60	97.55	15.45	96.98	17.10	96.36	18.73	95.68	20.34
c = .75	.74	.11	.74	.12	.74	.14	.73	.15
c = 1.00	.99	.15	.99	.16	.98	.18	.98	.20
c = 1.25	1.23	.18	1.23	.21	1.23	.23	1.22	.25

HORIZONTAL DISTANCES AND DIFFERENCES OF ELEVATION FOR STADIA MEASUREMENTS.

Minutes.	12°		13°		14°		15°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0'	95.68	20.34	94.94	21.92	94.15	23.47	93.30	25.00
2	95.65	20.39	94.91	21.97	94.12	23.52	93.27	25.05
4	95.63	20.44	94.89	22.02	94.09	23.58	93.24	25.10
6	95.61	20.50	94.86	22.08	94.07	23.63	93.21	25.15
8	95.58	20.55	94.84	22.13	94.04	23.68	93.18	25.20
10	95.56	20.60	94.81	22.18	94.01	23.73	93.16	25.25
12	95.53	20.66	94.79	22.23	93.98	23.78	93.13	25.30
14	95.51	20.71	94.76	22.28	93.95	23.83	93.10	25.35
16	95.49	20.76	94.73	22.34	93.93	23.88	93.07	25.40
18	95.46	20.81	94.71	22.39	93.90	23.93	93.04	25.45
20	95.44	20.87	94.68	22.44	93.87	23.99	93.01	25.50
22	95.41	20.92	94.66	22.49	93.84	24.04	92.98	25.55
24	95.39	20.97	94.63	22.54	93.81	24.09	92.95	25.60
26	95.36	21.03	94.60	22.60	93.79	24.14	92.92	25.65
28	95.34	21.08	94.58	22.65	93.76	24.19	92.89	25.70
30	95.32	21.13	94.55	22.70	93.73	24.24	92.86	25.75
32	95.29	21.18	94.52	22.75	93.70	24.29	92.83	25.80
34	95.27	21.24	94.50	22.80	93.67	24.34	92.80	25.85
36	95.24	21.29	94.47	22.85	93.65	24.39	92.77	25.90
38	95.22	21.34	94.44	22.91	93.62	24.44	92.74	25.95
40	95.19	21.39	94.42	22.96	93.59	24.49	92.71	26.00
42	95.17	21.45	94.39	23.01	93.56	24.55	92.68	26.05
44	95.14	21.50	94.36	23.06	93.53	24.60	92.65	26.10
46	95.12	21.55	94.34	23.11	93.50	24.65	92.62	26.15
48	95.09	21.60	94.31	23.16	93.47	24.70	92.59	26.20
50	95.07	21.66	94.28	23.22	93.45	24.75	92.56	26.25
52	95.04	21.71	94.26	23.27	93.42	24.80	92.53	26.30
54	95.02	21.76	94.23	23.32	93.39	24.85	92.49	26.35
56	94.99	21.81	94.20	23.37	93.36	24.90	92.46	26.40
58	94.97	21.87	94.17	23.42	93.33	24.95	92.43	26.45
60	94.94	21.92	94.15	23.47	93.30	25.00	92.40	26.50
c = .75	.73	.16	.73	.17	.73	.19	.72	.20
c = 1.00	.98	.22	.97	.23	.97	.25	.96	.27
c = 1.25	1.22	.27	1.21	.29	1.21	.31	1.20	.34

HORIZONTAL DISTANCES AND DIFFERENCES OF ELEVATION FOR STADIA MEASUREMENTS.

Minutes.	16°		17°		18°		19°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0'	92.40	26.50	91.45	27.96	90.45	29.39	89.40	30.78
2	92.37	26.55	91.42	28.01	90.42	29.44	89.36	30.83
4	92.34	26.59	91.39	28.06	90.38	29.48	89.33	30.87
6	92.31	26.64	91.35	28.10	90.35	29.53	89.29	30.92
8	92.28	26.69	91.32	28.15	90.31	29.58	89.26	30.97
10	92.25	26.74	91.29	28.20	90.28	29.62	89.22	31.01
12	92.22	26.79	91.26	28.25	90.24	29.67	89.18	31.06
14	92.19	26.84	91.22	28.30	90.21	29.72	89.15	31.10
16	92.15	26.89	91.19	28.34	90.18	29.76	89.11	31.15
18	92.12	26.94	91.16	28.39	90.14	29.81	89.08	31.19
20	92.09	26.99	91.12	28.44	90.11	29.86	89.04	31.24
22	92.06	27.04	91.09	28.49	90.07	29.90	89.00	31.28
24	92.03	27.09	91.06	28.54	90.04	29.95	88.96	31.33
26	92.00	27.13	91.02	28.58	90.00	30.00	88.93	31.38
28	91.97	27.18	90.99	28.63	89.97	30.04	88.89	31.42
30	91.93	27.23	90.96	28.68	89.93	30.09	88.86	31.47
32	91.90	27.28	90.92	28.73	89.90	30.14	88.82	31.51
34	91.87	27.33	90.89	28.77	89.86	30.19	88.78	31.56
36	91.84	27.38	90.86	28.82	89.83	30.23	88.75	31.60
38	91.81	27.43	90.82	28.87	89.79	30.28	88.71	31.65
40	91.77	27.48	90.79	28.92	89.76	30.32	88.67	31.69
42	91.74	27.52	90.76	28.96	89.72	30.37	88.64	31.74
44	91.71	27.57	90.72	29.01	89.69	30.41	88.60	31.78
46	91.68	27.62	90.69	29.06	89.65	30.46	88.56	31.83
48	91.65	27.67	90.66	29.11	89.61	30.51	88.53	31.87
50	91.61	27.72	90.62	29.15	89.58	30.55	88.49	31.92
52	91.58	27.77	90.59	29.20	89.54	30.60	88.45	31.96
54	91.55	27.81	90.55	29.25	89.51	30.65	88.41	32.01
56	91.52	27.86	90.52	29.30	89.47	30.69	88.38	32.05
58	91.48	27.91	90.48	29.34	89.44	30.74	88.34	32.09
60	91.45	27.96	90.45	29.39	89.40	30.78	88.30	32.14
c = .75	.72	.21	.72	.23	.71	.24	.71	.25
c = 1.00	.86	.28	.95	.30	.95	.32	.94	.33
c = 1.25	1.20	.35	1.19	.38	1.19	.40	1.18	.42

HORIZONTAL DISTANCES AND DIFFERENCES OF ELEVATION FOR STADIA MEASUREMENTS.

Minutes.	20°		21°		22°		23°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0'	88.30	32.14	87.16	33.46	85.97	34.73	84.73	35.97
2	88.26	32.18	87.12	33.50	85.93	34.77	84.69	36.01
4	88.23	32.23	87.08	33.54	85.89	34.82	84.65	36.05
6	88.19	32.27	87.04	33.59	85.85	34.86	84.61	36.09
8	88.15	32.32	87.00	33.63	85.80	34.90	84.57	36.13
10	88.11	32.36	86.96	33.67	85.76	34.94	84.52	36.17
12	88.08	32.41	86.92	33.72	85.72	34.98	84.48	36.21
14	88.04	32.45	86.88	33.76	85.68	35.02	84.44	36.25
16	88.00	32.49	86.84	33.80	85.64	35.07	84.40	36.29
18	87.96	32.54	86.80	33.84	85.60	35.11	84.35	36.33
20	87.93	32.58	86.77	33.89	85.56	35.15	84.31	36.37
22	87.89	32.63	86.73	33.93	85.52	35.19	84.27	36.41
24	87.85	32.67	86.69	33.97	85.48	35.23	84.23	36.45
26	87.81	32.72	86.65	34.01	85.44	35.27	84.18	36.49
28	87.77	32.76	86.61	34.06	85.40	35.31	84.14	36.53
30	87.74	32.80	86.57	34.10	85.36	35 36	84.10	36.57
32	87.70	32.85	86.53	34.14	85.3	35.40	84.06	36.61
34	87.66	32.89	86.49	34.18	85.27	35.44	84.01	36.65
36	87.62	32.93	86.45	34.23	85.23	35.48	83.97	36.69
38	87.58	32.98	86.41	34.27	85.19	35.52	83.93	36.73
40	87.54	33.02	86.37	34.31	85.15	35.56	83.89	36.77
42	87.51	33.07	86.33	34.35	85.11	35.60	83.84	36.80
44	87.47	33.11	86.29	34.40	85.07	35.64	83.80	36.84
46	87.43	33.15	86.25	34.44	85.02	35.68	83.76	36.88
48	87.39	33.20	86.21	34.48	84.98	35.72	83.72	36.92
50	87.35	33.24	86.17	34.52	84.94	35.76	83.67	36.96
52	87.31	33.28	86.13	34.57	84.90	35.80	83.63	37.00
54	87.27	33.33	86.09	34.61	84.86	35.85	83.59	37.04
56	87.24	33.37	86.05	34.65	84.82	35.89	83.54	37.08
58	87.20	33.41	86.01	34.69	84.77	35.93	83.50	37.12
60	87.16	33.46	85.97	34.73	84.73	35.97	83.46	37.16
c = .75	.70	.26	.70	.27	.69	.29	.69	.30
c = 1.00	.94	.35	.93	.37	.92	.38	.92	.40
c = 1.25	1.17	.44	1.16	.46	1.15	.48	1.15	.50

HORIZONTAL DISTANCES AND DIFFERENCES OF ELEVATION FOR STADIA MEASUREMENTS.

Minutes.	24°		25°		26°		27°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0'	83.46	37.16	82.14	38.30	80.78	39.40	79.39	40.45
2	83.41	37.20	82.09	38.34	80.74	39.44	79.34	40.49
4	83.37	37.23	82.05	38.38	80.69	39.47	79.30	40.52
6	83.33	37.27	82.01	38.41	80.65	39.51	79.25	40.55
8	83.28	37.31	81.96	38.45	80.60	39.54	79.20	40.59
10	83.24	37.35	81.92	38.49	80.55	39.58	79.15	40.62
12	83.20	37.39	81.87	38.53	80.51	39.61	79.11	40.66
14	83.15	37.43	81.83	38.56	80.46	39.65	79.06	40.69
16	83.11	37.47	81.78	38.60	80.41	39.69	79.01	40.72
18	83.07	37.51	81.74	38.64	80.37	39.72	78.96	40.76
20	83.02	37.54	81.69	38.67	80.32	39.76	78.92	40.79
22	82.98	37.58	81.65	38.71	80.28	39.79	78.87	40.82
24	82.93	37.62	81.60	38.75	80.23	39.83	78.82	40.86
26	82.89	37.66	81.56	38.78	80.18	39.86	78.77	40.89
28	82.85	37.70	81.51	38.82	80.14	39.90	78.73	40.92
30	82.80	37.74	81.47	38.86	80.09	39.93	78.68	40.96
32	82.76	37.77	81.42	38.89	80.04	39.97	78.63	40.99
34	82.72	37.81	81.38	38.93	80.00	40.00	78.58	41.02
36	82.67	37 85	81.33	38.97	79.95	40.04	78.54	41.06
38	82.63	37.89	81.28	39.00	79.90	40.07	78.49	41.09
40	82.58	37.93	81.24	39.04	79.86	40.11	78.44	41.12
42	82.54	37.96	81.19	39.08	79.81	40.14	78.39	41.16
44	82.49	38.00	81.15	39.11	79.76	40.18	78.34	41.19
46	82.45	38.04	81.10	39.15	79.72	40.21	78.30	41.22
48	82.41	38.08	81.06	39.18	79.67	40.24	78.25	41.26
50	82.36	38.11	81.01	39.22	79.62	40.28	78.20	41.29
52	82.32	38.15	80.97	39.26	79.58	40.31	78.15	41.32
54	82.27	38.19	80.92	39.29	79.53	40.35	78.10	41.35
56	82.23	38.23	80.87	39.33	79.48	40.38	78.06	41.39
58	82.18	38.26	80.83	39.36	79.44	40.42	78.01	41.42
60	82.14	38.30	80.78	39.40	79.39	40.45	77.96	41.45
c = .75	.68	.31	.68	.32	.67	.33	.66	.35
c = 1.00	.91	.41	.90	.43	.89	.45	.89	.46
c = 1.25	1.14	.52	1.13	.54	1.12	.56	1.11	.58

HORIZONTAL DISTANCES AND DIFFERENCES OF ELEVATION FOR STADIA MEASUREMENTS.

Minutes.	28°		29°		30°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0'	77.96	41.45	76.50	42.40	75.00	43.30
2	77.91	41.48	76.45	42.43	74.95	43.33
4	77.86	41.52	76.40	42.46	74.90	43.36
6	77.81	41.55	76.35	42.49	74.85	43.39
8	77.77	41.58	76.30	42.53	74.80	43.42
10	77.72	41.61	76.25	42.56	74.75	43.45
12	77.67	41.65	76.20	42.59	74.70	43.47
14	77.62	41.68	76.15	42.62	74.65	43.50
16	77.57	41.71	76.10	42.65	74.60	43.53
18	77.52	41.74	76.05	42.68	74.55	43.56
20	77.48	41.77	76.00	42.71	74.49	43.59
22	77.42	41.81	75.95	42.74	74.44	43.62
24	77.38	41.84	75.90	42.77	74.39	43.65
26	77.33	41.87	75.85	42.80	74.34	43.67
28	77.28	41.90	75.80	42.83	74.29	43.70
30	77.23	41.93	75.75	42.86	74.24	43.73
32	77.18	41.97	75.70	42.89	74.19	43.76
34	77.13	42.00	75.65	42.92	74.14	43.79
36	77.09	42.03	75.60	42.95	74.09	43.82
38	77.04	42.06	75.55	42.98	74.04	43.84
40	76.99	42.09	75.50	43.01	73.99	43.87
42	76.94	42.12	75.45	43.04	73.93	43.90
44	76.89	42.15	75.40	43.07	73.88	43.93
46	76.84	42.19	75.35	43.10	73.83	43.95
48	76.79	42.22	75.30	43.13	73.78	43.98
50	76.74	42.25	75.25	43.16	73.73	44.01
52	76.69	42.28	75.20	43.18	73.68	44.04
54	76.64	42.31	75.15	43.21	73.63	44.07
56	76.59	42.34	75.10	43.24	73.58	44.09
58	76.55	42.37	75.05	43.27	73.52	44.12
60	76.50	42.40	75.00	43.30	73.47	44.15
c = .75	.66	.36	.65	.37	.65	.38
c = 1.00	.88	.48	.87	.49	.86	.51
c = 1.25	1.10	.60	1.09	.62	1.08	.64

TABLE OF
RADII AND CHORD AND TANGENT DEFLECTIONS.

The formulas used in the computation of the following table are as follows:

For Radii, $R = \frac{50}{\sin D}$. **(89.)** Art. **1249.**

For Chord Deflections,

$$d = \frac{c^2}{R}. \quad \textbf{(92.)} \text{ Art. } \textbf{1255.}$$

For Tangent Deflections,

$$\tan \text{deflection} = \frac{c^2}{2R}. \quad \textbf{(93.)} \text{ Art. } \textbf{1255.}$$

TABLE OF RADII AND DEFLECTIONS.

Degree.	Radii.	Chord Deflection.	Tangent Deflection.	Degree.	Radii.	Chord Deflection.	Tangent Deflection.	Degree.	Radii.	Chord Deflection.	Tangent Deflection.
° ′				° ′				° ′			
0 5	68754.94	.145	.073	5 15	1091.73	9.160	4.580	10 50	529.67	18.880	9.440
10	34377.48	.291	.145	20	1074.68	9.305	4.653				
15	22918.33	.436	.218	25	1058.16	9.450	4.725	11 0	521.67	19.169	9.585
20	17188.76	.582	.291	30	1042.14	9.596	4.798	10	513.91	19.459	9.729
25	13751.02	.727	.364	35	1026.60	9.741	4.870	20	506.38	19.748	9.874
30	11459.19	.873	.436	40	1011.51	9.886	4.943	30	499.06	20.038	10.019
35	9822.18	1.018	.509	45	996.87	10.031	5.016	40	491.96	20.327	10.164
40	8594.41	1.164	.582	50	982.64	10.177	5.088	50	485.05	20.616	10.308
45	7639.49	1.309	.654	55	968.81	10.322	5.161				
50	6875.55	1.454	.727					12 0	478.34	20.906	10.453
55	6250.51	1.600	.800	6 0	955.37	10.467	5.234	10	471.81	21.195	10.597
				5	942.29	10.612	5.306	20	465.46	21.484	10.742
1 0	5729.65	1.745	.873	10	929.57	10.758	5.379	30	459.28	21.773	10.887
5	5288.92	1.891	.945	15	917.19	10.903	5.451	40	453.26	22.063	11.031
10	4911.15	2.036	1.018	20	905.13	11.048	5.524	50	447.40	22.352	11.176
15	4583.75	2.182	1.091	25	893.39	11.193	5.597				
20	4297.28	2.327	1.164	30	881.95	11.339	5.669	13 0	441.68	22.641	11.320
25	4044.51	2.472	1.236	35	870.79	11.484	5.742	10	436.12	22.930	11.465
30	3819.83	2.618	1.309	40	859.92	11.629	5.814	20	430.69	23.219	11.609
35	3618.80	2.763	1.382	45	849.32	11.774	5.887	30	425.40	23.507	11 754
40	3437.87	2.909	1.454	50	838.97	11.910	5.960	40	420.23	23.796	11.898
45	3274.17	3.054	1.527	55	828.88	12.065	6.032	50	415.19	24.085	12.043
50	3125.36	3.200	1.600								
55	2989.48	3.345	1.673	7 0	819.02	12.210	6.105	14 0	410.28	24.374	12.187
				5	809.40	12.355	6.177	10	405.47	24.663	12.331
2 0	2864.93	3.490	1.745	10	800.00	12.500	6.250	20	400.78	24.951	12.476
5	2750.35	3.636	1.818	15	790.81	12.645	6.323	30	396.20	25.240	12.620
10	2644.58	3.781	1.891	20	781.84	12.790	6.395	40	391.72	25.528	12.764
15	2546.64	3.927	1.963	25	773.07	12.936	6.468	50	387.34	25.817	12.908
20	2455.70	4.072	2.036	30	764.49	13.081	6.540				
25	2371.04	4.218	2.109	35	756.10	13.226	6.613	15 0	383.06	26.105	13.053
30	2292.01	4.363	2.181	40	747.89	13.371	6.685	10	378.88	26.394	13.197
35	2218.09	4.508	2.254	45	739.86	13.516	6.758	20	374.79	26.682	13.341
40	2148.79	4.654	2.327	50	732.01	13.661	6.831	30	370.78	26.970	13.485
45	2083.68	4.799	2.400	55	724.31	13.806	6.903	40	366.86	27.258	13.629
50	2022.41	4.945	2.472					50	363.02	27.547	13.773
55	1964.64	5.090	2.545	8 0	716.78	13.951	6.976				
				5	709 40	14.096	7.048	16 0	359.26	27.835	13.917
3 0	1910.08	5.235	2.618	10	702.18	14.241	7.121	10	355.59	28.123	14.061
5	1858.47	5.381	2.690	15	695.09	14.387	7.193	20	351.98	28.411	14.205
10	1809.57	5.526	2.763	20	688.16	14.532	7.266	30	348.45	28.699	14.349
15	1763.18	5.672	2.836	25	681.35	14.677	7.338	40	344.99	28.986	14.493
20	1719.12	5.817	2.908	30	674.69	14.822	7.411	50	341.60	29.274	14.637
25	1677.20	5.962	2.981	35	668.15	14.967	7.483				
30	1637.28	6.108	3.054	40	661.74	15.112	7.556	17 0	338.27	29.562	14.781
35	1599.21	6.253	3.127	45	655.45	15.257	7.628	10	335.01	29.850	14.925
40	1562.88	6.398	3.199	50	649.27	15.402	7.701	20	331.82	30.137	15.069
45	1528.16	6.544	3.272	55	643.22	15.547	7.773	30	328.68	30.425	15.212
50	1494.95	6.689	3.345					40	325.60	30.712	15.356
55	1463.16	6.835	3.417	9 0	637.27	15.692	7.846	50	322.59	31.000	15.500
				10	631.44	15.837	7.918				
4 0	1432.69	6.980	3.490	10	625.71	15.982	7.991	18 0	319.62	31.287	15.643
5	1403.46	7.125	3.563	15	620.09	16.127	8.063	10	316.71	31.574	15.787
10	1375.40	7.271	3.635	20	614.56	16.272	8.136	20	313.86	31.861	15.931
15	1348.45	7.416	3.708	25	609.14	16.417	8.208	30	311.06	32.149	16.074
20	1322.53	7.561	3.781	30	603.80	16.562	8.281	40	308.30	32.436	16.218
25	1297.58	7.707	3.853	35	598.57	16.707	8.353	50	305.60	32.723	16.361
30	1273.57	7.852	3.926	40	593.42	16.852	8.426				
35	1250.42	7.997	3.999	45	588.36	16.996	8.498	19 0	302.94	33.010	16.505
40	1228.11	8.143	4.071	50	583.38	17.141	8.571	10	300.33	33.296	16.648
45	1206.57	8.288	4.144	55	578.49	17.286	8.643	20	297.77	33.583	16.792
50	1185.78	8.433	4.217					30	295.25	33.870	16.935
55	1165.70	8.579	4.289	10 0	573.69	17.431	8.716	40	292.77	34.157	17.078
				10	564.31	17.721	8.860	50	290.33	34.443	17.222
5 0	1146.28	8.724	4.362	20	555.23	18.011	9.005				
5	1127.50	8.869	4.435	30	546.44	18.300	9.150	20 0	287.94	34.730	17.365
10	1109.33	9.014	4.507	40	537.92	18.590	9.295				

RULES AND FORMULAS.

THE TRIGONOMETRIC FUNCTIONS.

Art. **98.**

$$Sine = \frac{side\ opposite}{hypotenuse};\ therefore,$$

Rule 1.—*Side opposite = hypotenuse × sine.*

Rule 2.—$Hypotenuse = \frac{side\ opposite}{sine}$.

$$Cosine = \frac{side\ adjacent}{hypotenuse};\ therefore,$$

Rule 3.—*Side adjacent = hypotenuse × cosine.*

Rule 4.—$Hypotenuse = \frac{side\ adjacent}{cosine}$.

$$Tangent = \frac{side\ opposite}{side\ adjacent};\ therefore,$$

Rule 5.—*Side opposite = side adjacent × tangent.*

$$Cotangent = \frac{side\ adjacent}{side\ opposite};\ therefore,$$

Rule 6.—*Side adjacent = side opposite × cotangent.*

RULES FOR USING TRIGONOMETRIC TABLES.

Given, an angle, to find its sine, cosine, tangent, and cotangent.

Rule 7.—*Find in the table the sine, cosine, tangent, or cotangent corresponding to the degrees and minutes of the angle.*

For the seconds, find the difference of the values of the sine, cosine, tangent, or cotangent taken from the table, between which the seconds of the angle fall; multiply this difference by a fraction whose numerator is the number of seconds in the given angle, and whose denominator is 60.

If sine or tangent, add this correction to the value first found; if cosine or cotangent, subtract the correction. Art. **102.**

Given, the sine, cosine, tangent, or cotangent, to find the angle corresponding.

To find the angle corresponding to a given sine, cosine, tangent, or cotangent whose exact value is not contained in the table :

Rule 8.—*Find the difference of the two numbers in the table between which the given sine, cosine, tangent, or cotangent falls, and use the number of parts in this difference as the denominator of a fraction.*

Find the difference between the number belonging to the **smaller angle,** *and the given sine, cosine, tangent, or cotangent, and use the number of parts in the difference just found as the numerator of the fraction mentioned above. Multiply this fraction by 60, and the result will be the number of seconds to be added to the* **smaller angle.** Art. **105.**

RULES FOR MENSURATION.

THE TRIANGLE.

Rule.—*The area of any triangle equals one-half the product of the base and the altitude.* Art. **118.**

Let a, b, and c be the length of the sides, s half the sum of these lengths, and A the area of any plane triangle; then,

$$A = \sqrt{s(s-a)\,(s-b)\,(s-c)}, \text{ where } s = \frac{a+b+c}{2}.$$

Art. **119.**

THE QUADRILATERAL.

Rule.—*The area of any parallelogram equals the product of the base and the altitude.* Art. **129.**

Rule.—*The area of a trapezoid equals one-half the sum of the parallel sides multiplied by the altitude.* Art. **130.**

THE CIRCLE.

Rule.—*The circumference of a circle equals the diameter multiplied by 3.1416.* Art. **131.**

Rule.—*The diameter of a circle equals the circumference divided by 3.1416.* Art. **131.**

Rule.—*The length of an arc of a circle equals the circumference of the circle of which the arc is a part multiplied by the number of degrees in the arc, and divided by 360.* Art. **132.**

When only the chord of the arc and the height of segment are given, the following approximate formula may be used: Let c be the length of chord, h the height of segment, and l the length of arc; then,

$$l = \frac{4\sqrt{c^2 + 4h^2} - c}{3}. \qquad \text{Art. } \mathbf{133.}$$

To find the area of a circle:

Rule.—*Square the diameter, and multiply by .7854, or, square the radius and multiply by 3.1416.* Art. **134.**

Given, the area of a circle to find its diameter:

Rule.—*Divide the area by .7854, and extract the square root of the quotient.* Art. **135.**

To find the area of a sector:

Rule.—*Divide the number of degrees in the arc of a sector by 360. Multiply the result by the area of the circle of which the sector is a part.* Art. **137.**

Rule.—*The area of a sector is equal to one-half the product of the radius and length of arc.* Art. **138.**

To find the area of a segment of a circle:

Rule.—*Draw radii from the center of the circle to the extremities of the arc of the segment; find the area of the sector thus formed, subtract from this the area of the triangle formed by the radii and the chord of the arc of the segment, and the result is the area of the segment.* Art. **139.**

THE ELLIPSE.

To find the periphery (perimeter) of an ellipse:

Let $\pi = 3.1416$; C = periphery (perimeter); a = half the major axis; b = half the minor axis; $D = \frac{a-b}{a+b}$.

Then, $$C = \pi (a+b) \frac{64 - 3D^4}{64 - 16D^2}.$$

To find the area of an ellipse:

Rule.—*The area of an ellipse is equal to the product of its two diameters multiplied by .7854.* Art. **144.**

THE PRISM AND CYLINDER.

To find the area of the convex surface of any right prism or right cylinder:

Rule.—*Multiply the perimeter of the base by the altitude.* Art. **158.**

To find the volume of a right prism or cylinder:

Rule.—*The volume of any right prism or cylinder equals the area of the base multiplied by the altitude.* Art. **159.**

THE PYRAMID AND CONE.

Rule.—*The convex area of a right pyramid or cone equals the perimeter of the base multiplied by one-half the slant height.* Art. **164.**

Rule.—*The volume of a right pyramid or cone equals the area of the base multiplied by one-third of the altitude.* Art. **165.**

THE FRUSTUM OF A PYRAMID OR CONE.

To find the convex area of a frustum of a right pyramid or right cone:

Rule.—*The convex area of a frustum of a right pyramid or right cone equals one-half the sum of the perimeters of its bases multiplied by the slant height of the frustum.* Art. **169.**

To find the volume of the frustum of a pyramid or cone.

Rule.—*Add the areas of the upper base, the lower base, and the square root of the product of the areas of the two bases; multiply this sum by one-third of the altitude.* Art. **170.**

THE SPHERE.

Rule.—*The area of the surface of a sphere equals the square of the diameter multiplied by 3.1416.* Art. **172.**

Rule.—*The volume of a sphere equals the cube of the diameter multiplied by .5236.* Art. **173.**

To find the diameter of a sphere of known volume:

Rule.—*Divide the volume by .5236 and extract the cube root of the quotient.* Art. **174.**

FORMULAS USED IN SURVEYING.

RADIUS OF A CURVE.

To find the radius, the degree being given:

Let R = the length of the required radius;

D = the deflection angle equal to one-half the degree of the given curve.

$$R = \frac{50}{\sin D}. \qquad (89.)$$ Art. **1249.**

LENGTH OF SUB-CHORDS.

For curves of short radii:

Let C = the length of the required chord;

R = the radius of the given curve;

D = the deflection angle of the given curve, equal to one-half its degree.

$$C = 2R \sin D. \qquad (90.)$$ Art. **1250.**

LENGTH OF THE TANGENT OF A CURVE.

When the radius and intersection angle are given:

Let T = the length of the required tangent;

R = the radius of the given curve;

I = the intersection angle of the given curve.

$$T = R \tan \tfrac{1}{2} I. \qquad (91.)$$ Art. **1251.**

CHORD DEFLECTION.

When the length of the chord and the radius are given:

Let d = the required chord deflection;
c = the length of the chord of the given curve;
R = the radius of the given curve.

$$d = \frac{c^2}{R}. \qquad \textbf{(92.)} \quad \text{Art. } \textbf{1255.}$$

TANGENT DEFLECTION.

When the length of the tangent, or of its corresponding chord, and the radius are given:

Let c = the length of the tangent or corresponding chord;
R = the radius of the given curve.

$$\text{tangent deflection} = \frac{c^2}{2R}. \qquad \textbf{(93.)} \quad \text{Art. } \textbf{1255.}$$

Or, find the chord deflection as in the preceding formula and divide it by 2. The quotient is the required tangent deflection.

STADIA MEASUREMENTS.

To find the horizontal distance between two given points, the distance between them having been read with the stadia and the vertical angle taken:

Let D = the corrected or horizontal distance;
c = the constant;
$a\,k$ = the stadia distance;
n = the vertical angle.

$$D = c \cos n + a\,k \cos^2 n. \qquad \textbf{(94.)} \quad \text{Art. } \textbf{1301.}$$

To find the difference of elevation between two given points in stadia work:

Let E = the required difference in elevation;
c = the constant;
$a\,k$ = the stadia distance;
n = the vertical angle.

$$E = c \sin n + a\,k \frac{\sin 2\,n}{2}. \qquad \textbf{(95.)} \quad \text{Art. } \textbf{1301.}$$

BAROMETRICAL LEVELING.

To find the difference of elevation between two points with the aneroid barometer:

Let Z = the difference of elevation between the two given stations;

h = the reading in inches of the barometer at the lower station;

H = the reading in inches of the barometer at the higher station;

t and t' = the temperature (F.) of the air at the two stations.

$$Z = (\log h - \log H) \times 60{,}384.3 \left(1 + \frac{t + t' - 64°}{900}\right).$$

(96.) Art. **1304.**

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NOTE.—Items relating to the drawing section of this volume refer to two numbers, the first of which is printed on the inside edges of the headlines and is preceded by the printers' section mark (§); the second number refers to the page number. Hence, to find "bow-pen," the reference to which is given as § 13, page 9, look along the inside edges of the headlines until § 13 is found and then through Section 13 until page 9 is found. All references to the Tables and Formulas are printed under the following three headings: Formulas Used in Surveying, Rules and Formulas, and Tables.